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BIOLOGY

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ATWOOD









TEXT BOOKS IN SCIENCE FOR SECONDARY  
SCHOOLS

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# BIOLOGY

BY

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*338 Illustrations*

PHILADELPHIA

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1012 WALNUT STREET

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PRINTED IN U. S. A.  
BY THE MAPLE PRESS COMPANY, YORK, PA.

## PREFACE

All of the great principles of life operate in a uniform manner in the activities of plants, animals, and man. Digestion, respiration, irritability, reproduction, heredity, etc. are such activities. Several years ago the author became convinced that each activity of living things can be studied and understood more effectively if studied in a course in biology wherein plants, animals, and man are considered in one unit instead of repeating the study of each function separately three times and in different terms of the school year.

There are two types of biology texts. The one type is divided into three parts, and each activity or function must be taken up three times. There is no advantage in these texts over courses in botany and zoology. They are called biologies because they treat of the three provinces of biological knowledge. The other type treats activities and functions for plants, animals, and mankind in a united study. The author believes that the three part biologies are merely a transition stage in the change from botany and zoology teaching to true biology.

The greatest good and interest in biology teaching comes from gaining an understanding of the intimate relationships of plants and animals to man. This relationship can not be shown effectively and interestingly if a consideration of man is deferred to the end of the course.

Plants and animals are associated together in nature, and their activities are interdependent. It is the way of nature to think of them together, and it is the more natural method of observing and learning.

WM. H. ATWOOD.

MILWAUKEE,  
*March, 1927.*



## ACKNOWLEDGMENTS

Naturally an author owes a deep debt of gratitude to the many students who have inspired him, and from whom he has learned much about the methods of teaching and writing, by the method of "try and see." It is only by testing out our ideas with the class that we can be sure that we are right.

Our thanks are due the following educators who have assisted by reading manuscript and giving advice: Ida M. Atwood, Grant Cook, E. O. Finkenbinder, Chas B. Gates, Marjorie Jacques, Frank J. Mellencamp, Alvin L. Throne, and Harvey A. Uber.

We are also grateful to the following publishers for permission to use various illustrations which are separately acknowledged throughout the text: D. Appleton & Co., The Bobbs-Merrill Co., Ginn & Co., Henry Holt & Co., The Macmillan Co., A. I. Root & Co., The Wisconsin Farmer, and the Journal of Heredity.





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# BIOLOGY

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## UNIT I. THE STUDY OF BIOLOGY

### INTRODUCTION FOR STUDENTS AND TEACHER

**Biology** is the science of life, or the study of living things in reference to man and his institutions. The word is composed of two Greek words *bios* and *logos*. The first means "life" and the second means the "science of" or "a study of". The word was used for the first time by Treviranus in 1802 when he said, "What have Botany and Zoology been hitherto, but a dry register of names . . . ? But once regard systematic work as a part of Biology, and nomenclature (naming of plants and animals) as a means rather than as an end, and both take their place in science, contributing to the whole in which the intellect of man perceives the unity and harmony of Natural Law."

This was a century and a quarter ago. There have been great changes in the science, and its teaching since that time. To-day there are more students studying biology in our high schools than there are in botany and zoology classes combined, and the number is increasing. It would be inspiring, indeed, if Treviranus could return to earth and look in on a modern class in high school biology. He would be pleased beyond measure to note how far we have left the dry register of names, classification, and nomenclature behind, and have developed those phases of the subject which have a valuable bearing on our lives and our society.

Our modern courses in biology place emphasis upon the relations of plants and animals to man rather than upon the study of plants and animals to gain a knowledge of plant and animal life, or structure. These new courses are often called "civic biology", "eco-



onomic biology", or "social biology" to emphasize this trend, and this is the type of course which we shall study from this book.

**Life** is the most interesting thing in the world, and the very fact that we do not know what it is makes us the more anxious to learn more about it. If you were asked to define electricity, you would not be able to tell what it is, because we do not know; but you would be able to tell many things that it will do. It is very much the same with life. We know many valuable things about the lives of plants and animals, and we make great use of this knowledge, but life itself is a mystery.

**Protoplasm.**—At this place in our course we shall try to be content with the statement that living things differ from things which are not alive in that they are composed of *protoplasm*, and to make a few brief remarks about it.

**Materials which are not alive** may be composed of some of the ninety different kinds of elementary matter, either in combinations of various of these *elements*, or of elements existing alone. Iron, copper, sulphur, carbon, oxygen, and nitrogen are examples of elements which exist alone; and stone, water, carbon dioxide, iron ore, and salt are examples of various combinations of simpler substances.

**Materials which are alive**, with few exceptions, are composed of combinations of twelve of the ninety elements. These twelve elements and their abbreviations, which are the symbols used by chemists, are listed in the table.

|                    |   |                   |    |
|--------------------|---|-------------------|----|
| 1. Oxygen.....     | O | 7. Calcium.....   | Ca |
| 2. Carbon.....     | C | 8. Potassium..... | K  |
| 3. Hydrogen.....   | H | 9. Sodium.....    | Na |
| 4. Nitrogen.....   | N | 10. Iron.....     | Fe |
| 5. Phosphorus..... | P | 11. Silicon.....  | Si |
| 6. Sulphur.....    | S | 12. Chlorine..... | Cl |

We may say of protoplasm that it is composed of various combinations of these twelve elements. This gives us some idea as to the chemistry of protoplasm, but this is not the most wonderful thing about it as compared to minerals. Protoplasm possesses the energies of life. It moves, it grows, it renews itself when injured, it reproduces itself with each new generation, and in the form of brain matter it may be the vehicle of thought. So it is that this combination of

living matter and energy is alive, or is life; and it is this wonderful and mysterious field of knowledge that we are to study in this course.

**This book** is divided into eleven units. All but two of the units are subdivided into studies, lessons, or problems. Each unit deals with information which is closely related. Some of the studies are presented as problems because we are more interested in what we learn if it appears before us as a problem which is not known to us and which we desire to solve or understand, but they are not all developed in this manner because all biological study does not lend itself to this method of teaching. In each case the method which has been found to be the best suited to the information to be had is used.

**How Shall We Study Biology?**—Can one become a great biologist by committing the facts written in this book to memory? The author thinks that you should read the story of the division of the unit as it is assigned each day, and that you should learn it all, but this is only book knowledge. It guides you, it helps you, it corrects you; but real biological knowledge must be had from nature herself. You will go to the fields, the woods, the water bodies, the laboratory, the farm, and to many other places if you are to learn biology. You must be alert and observe keenly.

**Excursions.**—When the class, or a committee, makes a trip to the fields or woods specimens should be secured and brought to the laboratory for study. Among the interesting things which may be brought in are insects, minnows, frogs, turtles, ant colonies, deserted wasp nests, galls, deserted bird nests, salamanders, small snakes, field mice, snails, water plants, mosses, ferns, weeds, fruits, seeds, burs, nuts, twigs, leaves, fungi, and roots. If live animals are kept they should be well fed and comfortably caged.

**Quizzes** stimulate students to study. They test the accuracy of ideas and give training in expression. They may be oral or written, and should always be studied for in advance. Questions of a general nature which we can not always fully answer are supplied at the beginning of each problem. More definite questions are given at the end of each problem. The general questions are for the purpose of opening the student's mind, and the review questions test one's understanding of the lesson after it has been studied. An

outline is also given to help the student to review and reconstruct the information of the study or problem.

**Reports** may be given whenever a student has worked out a problem, experiment, project, investigation, etc.

When you recite or give reports, remember that you must make your remarks interesting to the class. Speak clearly, use good English, have your thoughts well outlined, face the class. What is the use in saying something if you do not interest your hearers, and do not make them understand?

**Coöperation** must be the slogan of every successful biology class. Work together, and thus learn to work with your fellows in all of the fields of life. Team work succeeds, obstinacy and stubbornness usually fail. *Discipline* and *loyalty* are the essentials of good team work. The people of a community prosper when they work together, each for all and all for each. You want your work to be pleasant and successful and to this achievement you must all coöperate.

## UNIT II. HOW PLANTS AND ANIMALS LIVE

In this unit we shall try to see how some typical plants and animals live. We shall learn about the parts of a plant, and how they work together. Every plant and animal must get food and build it into its body. We shall try to find the source of this food and how it is used to make leaves, stems, roots, and flowers. We shall also try to find out how animals get food from plants, and learn that all food is first made by plants and then obtained by animals when they eat leaves and grass. We shall also see how plants reproduce by forming seeds and how the flowers of plants produce seed. Animals produce eggs for the same purpose. We shall want to know where they are laid and how they develop into fully grown grasshoppers, or bees, or other kinds of creatures.

We shall learn about the homes of plants and animals and how they are fitted to live in various places. Every plant and animal is especially fitted to live in the places where it is found and can not live in places to which it is not suited.

## STUDY I. THE LIFE OF THE GOLDENROD

**General Questions.**—What is a plant? What are the parts of a typical plant? What work do roots do for the whole plant? What are the special and general uses of stems? What is the value of leaves? Why do plants have flowers? How does the goldenrod distribute its seeds? How is the goldenrod related to its environment?

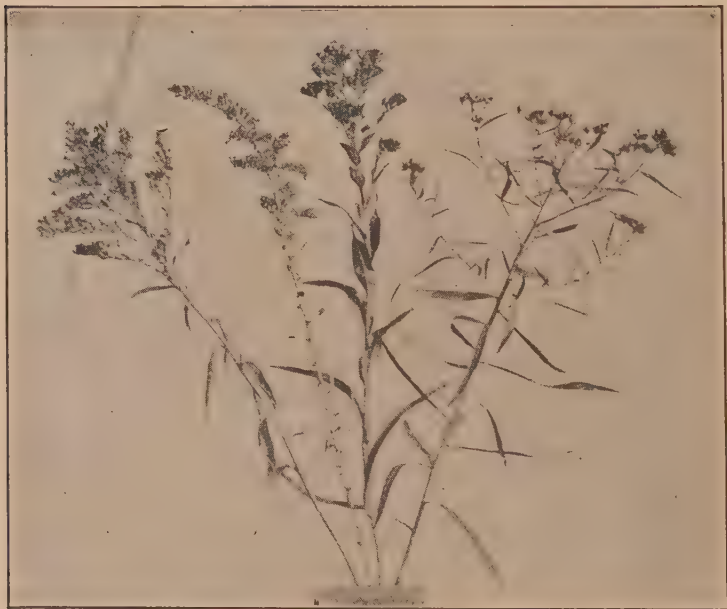


FIG. 1.—Four different species of goldenrod. Find several kinds of these plants and show them to the class.

**Field Trips.**—We are now ready to go out into the fields and study a typical plant and see how it lives. In the autumn the untilled fields invite us to go forth and admire the rich, yellow flower clusters

of the goldenrod. It is found everywhere in open fields of waste land.

Like most other plants the goldenrod is composed of four different kinds of structures, each having its special work to do for the good of the whole plant. These structures are the roots, the stem, the leaves, and the flowers. We shall take them up in their turn and study them.

**The roots** of the goldenrod are numerous, small in diameter, all of about the same size, and spread in all directions. This type of root is called a *fibrous root* (Fig. 2).



FIG. 2.—The underground parts of the goldenrod. A, last year's stem; B, the present stem; C, the stems which will grow next year.

If we try to pull a plant out of the ground we will find that the roots hold it firmly and that it is necessary to break them off before the plant comes out. This is one of the chief uses of roots. The roots also gather water containing mineral matter from the soil and this is absorbed by the plant to be changed by it into its food.



**The stem** of the goldenrod grows tall and erect, and the numerous leaves are arranged around it all the way from the bottom to the top. The tall stem lifts the leaves above those of other weeds and thus supplies them with an abundance of sunlight. The stem also carries the food material from the roots to the leaves and returns the food products made in the leaves to the roots.

If we loosen the soil about the roots of a goldenrod plant and pull it up, we shall find that from the base of the upright stem there are several slender, white stems running out in all directions from the parent plant. These stems are known as *underground stems* and keep the plant alive over winter when the upright stem is killed by the frost. From the end of each underground stem a new plant will grow up the next spring, and since there are several of these stems, there will be several plants growing next year where there is only one now. This is an important method of reproduction of goldenrod plants and causes them to grow together in patches. It is seldom that you find one growing alone.

Thus, we see that the goldenrod stems are of two kinds. The erect stem lifts the leaves into the sunlight and supplies sap. The underground stem preserves the life of the plant over winter and multiplies the number of individuals.

**The leaves** are arranged in close spirals around the stem and project outward and upward. Is this a good arrangement for the maximum exposure of leaf-surface to the rays of the sun? Are the leaves arranged the same way on other kinds of plants which you find in the field?

The leaves make food for the plant, respire, and throw off waste products to the air. These important functions will be more fully described later on. If you examine the leaf closely you will find that there are small veins running all through it. These veins are bundles of very small tubes which conduct the sap through the leaf. Compare the arrangement of the veins in the leaf of the goldenrod with those in the leaves of other plants which you find in the field. The leaves around the base of the stem are withered. One of the causes of the death of these leaves is that they have been shaded by the leaves higher up, and not being able to perform their work properly, they have died. Look for this same condition on other plants.



**The Flower.**—At the top of the plant many branches spread out from the main stem. These branches bear smaller branchlets upon which the little yellow flowers grow. How is the branch arrangement related to the leaf arrangement? (Fig. 1.)

If it is a bright day you will notice insects working busily among the flowers of the goldenrod. They are gathering nectar and a yellow powder called pollen. As they crawl over the flower cluster some of the pollen which adheres to their bodies is dusted off and falls among other blossoms. In this way they carry pollen from flower to flower. If this pollen is not transferred from flower to flower no seeds



FIG. 3.—Late in the fall the seeds are ripe and the flower-clusters are heavy with their precious burden. The seeds are released, a few at a time, throughout the winter.

Find other plants in the fields which retain their seeds in the early autumn. Learn their names and discover how their seeds are carried to new localities. Report your findings to the class.

will be produced. Some pollen may be carried by the wind, but insects are better carriers. Nectar, perfume, and color in flowers are the means of attracting insects in order that they may do this important work. The plant, however, exercises no consciousness in securing this service. Does the arrangement of the flowers in a cluster make them more conspicuous than they would be if they were scattered over the plant?

**Seed.**—The function of the flower is to produce seed. Find a plant that has produced its seed. Examine them closely and you will find that they are provided with a tuft of fine hair-like structures.

If you blow them, they will go sailing away. In a strong wind they may be carried great distances. They finally fall to the ground where they remain until spring. If nothing disturbs them, they will germinate and establish another patch of goldenrods. Thus, the plant is distributed and multiplied by the seeds which it produces and sends sailing away on the wind. As we study more of biology we will come to know that it is not enough for a plant to reproduce itself. It must also distribute its offspring to new places, and it must reestablish itself in places where it has lived and, for some reason, has died out.

**Relation to Environment.**—The goldenrod is truly a North American flower. Its scientific name is *Solidago*. Under this name 56 different kinds are known. Only a few species are found outside of the North American Continent. In Europe it is considered so beautiful that it is cultivated in flower gardens. Its various forms are adapted to grow everywhere from Canada to Mexico. Some live in swamps, some in deep woods, some on the dry western plains, but the untilled fields and fence rows furnish a home for the majority of species.

By means of its underground stems and extensive root system it makes preparation the fall before for the next season's growth. Early in the spring it sends up its wand-like stem and gets a good start before other plants which grow from seed can occupy the ground. The straight stems and long, narrow leaves enable the plants to stand close together and yet avoid shading one another. Its numerous, tufted seeds are distributed everywhere by the autumn and winter winds. It withstands successfully the frosts of winter, whilst the drought of summer hardly checks its growth. It is admirably fitted in every way to live in the North Temperate Zone which is its home.

#### OUTLINE-SUMMARY

**The Parts and Uses of the Goldenrod.**—Roots serve as anchors and gather soil water. Stems lift up the leaves and transport sap if they are upright. Underground stems preserve the life of the plant in winter and aid in reproduction.

Leaves prepare food, respire, and throw off waste products. The flowers are yellow and produce nectar, perfume, and pollen. The seeds are formed from the flower and are distributed by the wind. Their function is to reproduce the plant.

The 56 different species of the goldenrod are adapted to live in many different situations on the North American Continent.

**Review Questions.**—When does the goldenrod blossom? Describe its flowers. Name the parts of a typical plant. What is the chief function of each part? Describe the underground stems of the goldenrod. What are their special advantages? Why do old leaves fall off? Why do insects visit the goldenrod? What is the value of pollen? What are the advantages of nectar, color, and perfume? Of what advantage are the tufts of hair on the seeds? In what places are goldenrods found?

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#### STUDY 2. THE LIFE OF THE GRASSHOPPER

**General Questions.**—What are the general characteristics of an animal? Is the grasshopper a typical animal? Where do grasshoppers live? Of what parts is its body composed? How does it move from place to place? How does it get its food? How does it escape from its enemies? How does it grow? How does it provide for the next generation? How do its parts work together to maintain its life? What is the economic importance of the grasshopper? How is it related in classification to other insects?

Insects exist in greater variety than any other kinds of animal life. There are about one million different kinds of animals in the world and more than one half of them are insects. We have made a study of a typical plant, the goldenrod, and now we shall study a typical animal, the grasshopper.

There are many different kinds of grasshoppers. They are found in many parts of the world and may be had for study by going out

into the fields in the late summer, or early fall, and catching them with an insect net; but perhaps the better way to obtain large ones is to buy the lubber grasshoppers from dealers in biological supplies.

**Suggestion.**—It will be an interesting project to begin making a collection of the different kinds of grasshoppers which are found in your community. They may be found in the vacant lots of cities as well as in the country. As you collect them, note what they are doing. How do they crawl? How far can they fly? Do they make a sound? How do they make it? Are they difficult to catch? Can they hear? How far can they see? What kinds of plants do they eat? Are they destroying vegetables or crops? Do their colors protect them by making them difficult to see? Hold one in your hands and note how it breathes. Take hold of one of the large legs and test its strength.

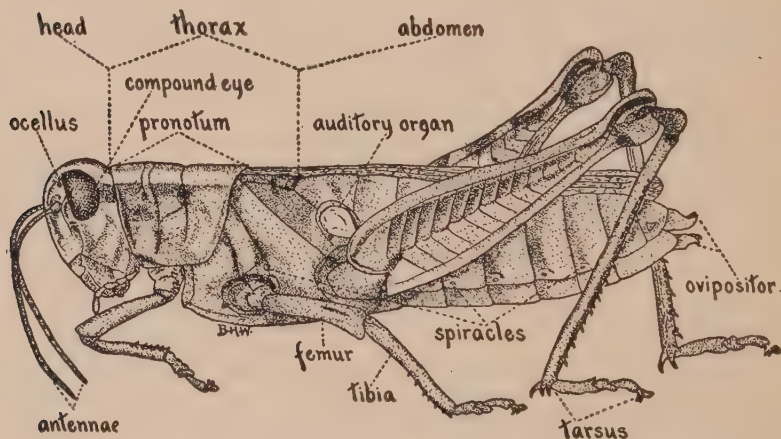


FIG. 4.—Side view of a grasshopper to show the parts mentioned in this study. The left wing has been cut off to show the "ear," or auditory organ. (Walden.)

**Structure.**—Every animal is composed of various parts which work together to do all of the many things which every animal must do to maintain its life and provide for another generation to take its place when it dies. The grasshopper's body is composed of a series of rings called *segments*, and these rings are grouped into three regions which are the *head*, *thorax*, and *abdomen*.

**The head** (Fig. 5) is composed of five segments, but they are so completely fused that it will be difficult to distinguish them. The

most important, and most prominent organs of the head are the *feelers*. The scientific name for them is *antennæ* (ăn-těn'ē). They are used for smelling as well as feeling. The grasshopper, like many other insects, has five eyes. It has two very large *compound eyes* and three *simple eyes* (ocelli). The compound eyes are composed of many parts each of which may be looked upon as an eye. They are closely set together and look like the cells of honeycomb. The three *simple eyes* resemble tiny glass beads. One is situated in the

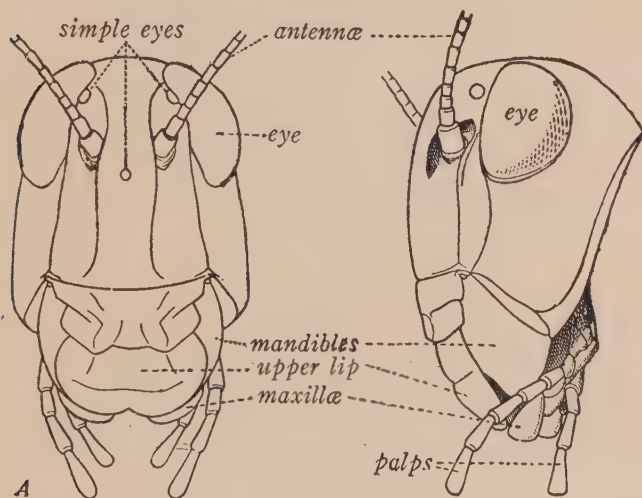


FIG. 5.—Front and side views of the head of a grasshopper. (Relabeled from Folsom.)

middle of the face in front, and one is on each side of the head just in front of each compound eye and near the base of each feeler. It may be necessary to use a lens to find them.

The other features of importance on the head are the mouth-parts. They consist of an *upper lip* and a *lower lip* which enclose two pairs of chewing parts. The heavy, black pair are called *mandibles* (măn'dīb' ls), and the second pair are called *maxillæ* (măks-ıl'lē). On each side of the mouth you will find a pair of structures which look like short feelers. One is attached to each maxilla, and one



to each side of the lower lip. They are called *palps*, from the word "palp" which means to touch.

**The thorax** is the middle portion of the body and serves as the place for the attachment of the wings and legs. The first segment of the thorax is the *collar* and bears the first pair of legs. Examine a specimen and be able to tell the differences between the first and second wings. Note also the very large size of the jumping legs. The wings and legs are the grasshopper's means of locomotion.



FIG. 6.—The wings of a grasshopper. Note that the first pair are leather-like and that the second pair can be folded like a fan. (Folsom.)

Animals must move about to seek food, to find their mates, and to escape from their enemies.

**The abdomen** of an insect bears no wings or legs. It is composed of rings which are broken along each side to permit the abdomen to expand and contract in breathing. Observe this process in a live insect. The air enters and leaves the abdomen through small holes, one on each side of each segment. These are found in all insects and are called *spiracles* (spir'a-k' ls). Insects do not breathe through their mouths. The *auditory organ* or "ear" of the grasshopper is an oval spot on the first segment of the abdomen. Find

it on a specimen. The grasshopper can not hear all sounds, but does hear the sounds which other grasshoppers make very well, and it probably hears some sounds which help it to escape from an approaching enemy. At the end of the abdomen in the females, are processes which are used in placing the eggs in the ground when they are laid. They are called *ovipositors*, which means egg depositors.

**Food getting** is necessary in the life of each animal.

As we go on with our study of biology we shall see that all food originates in the green tissues of plants. Animals do not make food as plants do. Some animals eat plants and are called *vegetarians*; and some animals eat other animals and are called *carnivores*.

Grasshoppers very seldom eat flesh, but they eat nearly every kind of green plant, as well as toadstools which are not green. Many grasshoppers hatch from eggs in the spring and begin to eat grass and leaves. You do not notice them at this season because they are so small; but as they grow, they become more conspicuous, and in the

fall of the year many leaves show where they have made their meals. Infrequently in August, in dry weather, they eat nearly every green plant, even stripping the leaves from the trees.

**Growth.**—When a grasshopper hatches from the egg in the spring, it looks very much like an adult, but has a larger head and has no wings. These cute little baby grasshoppers are called *nymphs*

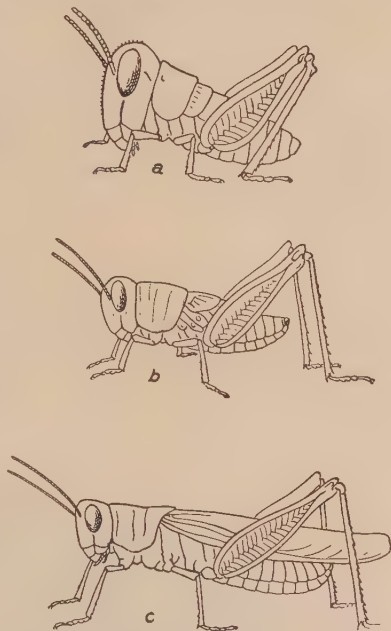


FIG. 7.—Three stages in the growth of the grasshopper. Compare the size of the head in each figure. Note that young grasshoppers do not have wings. (From Herms "Medical and Veterinary Entomology," by Permission of the Macmillan Company, Publishers.)



(nymphs). They grow directly into adult grasshoppers by a series of stages of growth. The outer covering of an insect is tough and dry. At times it is shed, and at each shedding of the "skin" the grasshopper gets larger. At the last stage of growth the wings appear fully formed. Then the insect is said to be *adult*, or fully grown, after which it never sheds its outer covering again. This process of growth is called *metamorphosis* (mět-a-môrfō-sīs). Grasshoppers are said to have *direct metamorphosis*; but such insects as butterflies are said to have an *indirect metamorphosis* because they do not look like the adults when they are young, and they pass through a stage of semi-dormancy (partial rest) as a *chrysalis* before becoming adults. Some authors speak of *complete* and *incomplete metamorphosis*, but "direct" and "indirect" are better terms, because every insect which reaches maturity "completes" its metamorphosis. Insects which have an indirect metamorphosis are the flies, beetles, caddice flies, butterflies, moths, ants, bees, and wasps. Nearly all others hatch from the egg as nymphs and develop directly.

**Reproduction** is an important function of all life. If a species of animal fails to continue to provide for the next generation, it will

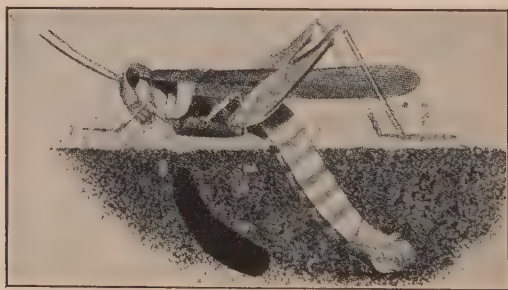


FIG. 8.—Grasshopper laying its eggs. The black figure beneath the insect represents the relative size and shape of the egg case after it is laid. (Gibson.)

become extinct. Grasshoppers, with few exceptions, lay their eggs in the fall of the year in the ground. A small hole is made, and the abdomen is thrust into it, and the eggs are laid in a neat little packet. The adults die at about the time of the first frost, so there are no living grasshoppers of these species in winter. The eggs preserve the life of the race over winter and hatch in spring. There is one

group of very small grasshoppers which are different from others of the family of grasshoppers in that they are able to resist the cold of winter and live as adults to lay their eggs in the spring; but they are exceptions to the general method.

We have described how the grasshopper grows by shedding its skin several times, eating all the while, and finally becomes fully grown.

The **digestion** of the grasshopper is characteristic of animals. Its food is chewed in the mouth, passes through an *esophagus* and accumulates in a *crop*. While it is being chewed, it is mixed with a brown *saliva* which may be seen exuding from a specimen's mouth if it is held in the hand. The boys sometimes call this "tobacco juice."

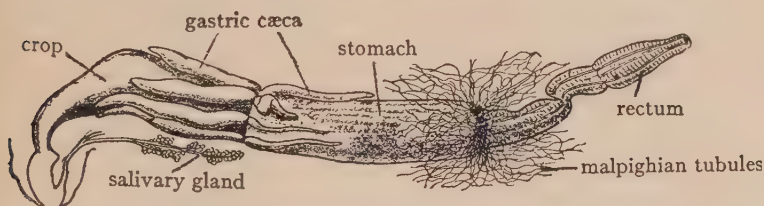


FIG. 9.—The digestive system of the grasshopper. (Folsom.)

In the **stomach** the food is acted upon by the digestive juices and is passed into the intestine to be absorbed into the blood. Surrounding the stomach are long pouches called *cæca* (sing. *cæcum*). Some of the food passes into them and is absorbed.

**Oxygen** is obtained through the spiracles as we have noted. From these openings, small tubes lead to all parts of the body and carry oxygen wherever it is needed. They also carry carbon dioxide back to the air outside. Oxygen combines with various substances in the body of animals and liberates energy for carrying on the life of the individual. Water and carbon dioxide are the chief products of this action. They must be discharged from the body, and the process of getting rid of them is called *excretion* (ěks-krě' shun). The many small tubes which carry oxygen in, and the carbon dioxide out, are called *tracheæ* (tră' ka-ě). Thus we see that the grasshopper breathes for the same reason that we do. The process is called *respiration*.

The blood of the grasshopper is not red as it is in us, but it does about the same work. It carries food to all parts of the body, and returns waste products to the organs which throw them off. Much

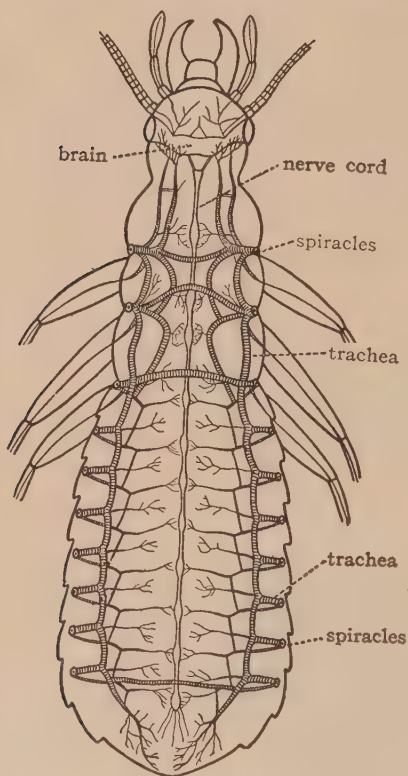


FIG. 10.

FIG. 10.—Diagram of the tracheal system of an insect. Note how the branches of the system go to all parts of the body. (Kolbe.)

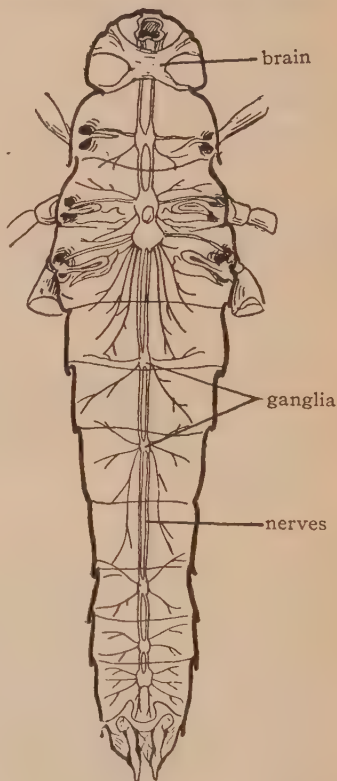


FIG. 11.

FIG. 11.—The nervous system of the grasshopper to show its ladder-like appearance. Where are the ganglia the largest? Which somites have the most work to do? (Snodgrass.)

of the waste matter is collected by long, slender tubes which carry it to the middle region of the intestine and pour it into this tube to be excreted with the waste products of digestion. These tubules are called *malpighian tubules* after a great Italian physiologist named

**Malpighi.** In insects the blood does not distribute oxygen as it does in other animals, and perhaps for this reason the blood vessels are not fully developed. There is a long "heart" in the dorsal (upper) part of the body. The blood flows slowly through it toward the head. The movement of blood through vessels is *circulation*.

**The nervous system** of the grasshopper consists of a chain of ganglia along the ventral (lower) side of the body. There are two of these in the head, one above and one below the esophagus. The ganglia are connected by double strands of nerves, so that the nervous system is somewhat like a ladder. Except in the head, there is a ganglion in each segment. The nervous system controls all of the activities of the body and all of its parts.

#### OUTLINE-SUMMARY

The grasshopper is a typical animal. It will be interesting to make a collection of grasshoppers and study them in the fields.

Structure, segments:

| Head          | Thorax | Abdomen     |
|---------------|--------|-------------|
| antennæ       | collar | spiracles   |
| compound eyes | legs   | ear         |
| ocelli        | wings  | ovipositors |
| lips          |        |             |
| mandibles     |        |             |
| maxillæ       |        |             |
| palps         |        |             |

The food of the grasshopper.

Growth, metamorphosis (direct and indirect), nymph, adult.

Grasshoppers lay their eggs in the fall and then die. The eggs live over winter and hatch in the spring. The "skin" is shed several times as the nymphs grow.

Digestion, esophagus, crop, saliva, stomach, cæca, intestine.

Oxygen is taken in and carbon dioxide is given off in respiration.

The blood carries food and waste, but not oxygen in circulation.

The nervous system is on the ventral side of the body and controls the grasshopper's activities.

**Review Questions.**—What are segments? Describe the grasshopper's head. Describe the thorax. Describe the abdomen. What does the grasshopper eat? Describe the growth of the grasshopper from the egg to the adult. What is meant by direct and indirect metamorphosis? How do grasshoppers lay their eggs? How does the grasshopper digest its food? Name the parts of the food tube. What work does the blood do? What work does the nervous system do?

### LABORATORY WORK ON THE GRASSHOPPER

**Make a sketch** of the side view of the grasshopper to show the features mentioned below. The body of an insect is divided into three divisions,—the **head**, **thorax**, and **abdomen**. Find the large **compound eyes**. Examine them with a lens to see the facets. Can the grasshopper see in all directions at one time without moving his head? The three **simple eyes** will be seen with the aid of a lens. One is in the middle of the face, and another before each compound eye. They appear as small beads.

The **antennæ** are possessed of how many joints? How great is their range of movement?

The **mouth-parts** are shown here in figures. Find them in your specimen and learn the names of their parts.

The **thorax** is composed of three parts (segments). The first is called the **collar**. It is movable on the body. Note that it bears the first pair of legs. The second division bears a pair of wings and a pair of legs as does the third. The divisions of the thorax are called the **prothorax**, **mesothorax**, and **metathorax**.

Compare the two pairs of **wings**. Which pair does the most of the flying? How does the grasshopper make its sounds? Do you know how the katydid, cricket, and cicada make their sounds?

Study the **leg** of an insect. The first two parts are small and difficult to make out. They are the **coxa** and **trochanter**. The **femur** is the largest part of the leg. It is followed by the slender **tibia**, and the foot is the **tarsus**. Compare the legs of the grasshopper with those of other insects.

**Draw** an insect's leg and label the parts.

The **abdomen** is composed of rings (segments). How many are there? The first ring is incomplete in the grasshopper and contains the ear.

If a live specimen is available, its respiration should be observed. The abdomen will be seen to swell and contract as air is taken into the **tracheal system** and let out again. Count the **spiracles** along each side of the abdomen. You should be able to find two on each side of the thorax also. An **ovipositor** consisting of two or more spines is usually found at the end of the abdomen of female insects.



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## STUDY 3. THE LIFE OF THE HONEYBEE

**General Questions.**—Why is the bee studied in addition to the grasshopper? Is the bee a highly specialized type of animal life? How many kinds of bees make up a colony and what are the duties of each? What materials are used by bees in making a home? Why do they swarm? What is their economic importance?

We have seen how the grasshopper is a typical animal and insect; but if we wish to study an insect which is intimately related to the goldenrod plants, and one which has remarkable adaptations for an insect, we may well choose the honeybee. Another reason why we should study the bee now is that it represents the highest degree of a form of social life which is different from ours. Our intelligence is based on *habit* and *reason*, and the social life of the bee is based on *instinct*. The social life of the bee hive appears to be almost as complicated as our own and the degree of coöperation between individuals is much greater. It is notable that all this can be done without purpose or judgment.

You may see the bees at work on the blossoms of the goldenrod early in the fall. They compete with many other insects for the food which is there in abundance. The yellow pollen is a valuable food for bees. They are literally covered with it and look like little golden flies. The pollen is scraped off and placed in pollen baskets on their legs. Watch them do this in the field. They are able to gather nectar and pollen at the same time. The nectar is taken up by their mouth parts which are modified to form a sucking, tube-like structure. The nectar passes to a chamber near their stomach which is called the *honey sac*. When they are loaded with pollen and filled with nectar, they fly high up into the air and make a "bee line" for their hive. Their sense of direction is wonderful.

We have seen in a previous study how the color and perfume of flowers attract flower-visiting insects. We have also seen how the bee renders a service to the goldenrod by distributing pollen from blossom to blossom, without which no seeds would be formed. We have here a remarkable case of coöperation between the bee and the goldenrod for the benefit of both. This relationship has become so

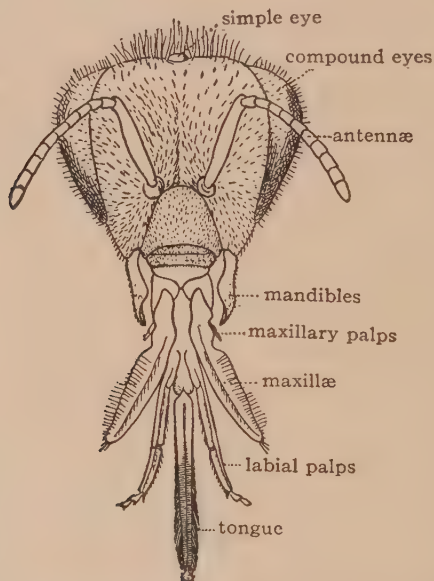


FIG. 12.—The head of the honeybee. Note the large compound eyes and the jointed feelers. Note also the mouth-parts and that they have the same names as those of the grasshopper but are modified for gathering nectar instead of chewing leaves. (From Herms "Medical and Veterinary Entomology", by Permission of the Macmillan Company, Publishers.)

complete and highly perfected between insects and flowers that many insects and many plants could not exist without it. The insects would starve and the plants would not be able to produce seed, thus both would perish.

The bee is a typical insect and does not differ materially from the grasshopper which we have studied. Make a careful observation of both insects and be able to tell of the differences and similarities of the two. We will not discuss the structure of the bee, but will



give what time we have to a consideration of its social life in the hive

The **beehive** contains three kinds of bees. Nearly all animals about which we know, appear as males and females; but honeybees appear as males and two kinds of females. One kind of female is known as the *queen* of which there is only one in a hive. The other type of female is known as a *worker* of which there may be several thousand in a hive. The males are known as *drones*. They do no work except to mate with a queen, and this mating takes place but once, and that is usually with a drone from some other hive. It is for this reason that drones are thought to be lazy fellows, but they



FIG. 13.—The three types of bees found in the hive. The drone at the left is heavy bodied and has long wings. The queen's body is long and large. The worker is much smaller than either of the others.

are very active, beautiful, and graceful. Although they make no honey, the work which they do is necessary. The queen does no work either, but she lays all of the eggs for the colony and is the mother of all of the bees in the hive. This keeps her occupied day and night.

The **workers** have so many duties to perform, and do them so perfectly, that it will be impossible to mention them all. They gather nectar and pollen from flowers. Out of this they make *honey* and *beebread*. They gather a kind of resin called *propolis* with which they seal up their hive against leakage in time of rain. They produce *wax* from glands in their bodies, and build *honeycomb* out of it. They care for the young; clean and ventilate the hive; and in time of trouble, they quickly give their lives in defense of the colony. Perhaps the most interesting thing about all of this is that there is

no supervision, no bossing, and no shirking. Each bee does its work by instinct because that is the way it must act. In this form of society nearly everything seems to be perfect so long as everything goes well, but when new situations with which the bee's instinct can not deal arise, the colony may perish. This is the great defect of the bee's social life. Not being possessed of reason, the bee does not know how to solve a problem if one arises in its life.



FIG. 14.—A section of honeycomb showing capped honey at the top, sealed and unsealed brood, and queen cell. (Root, *A B C and X Y Z of Bee Culture*.)

The substances found in a hive are *honey*, *pollen*, *propolis*, and *wax*. The honey and pollen are gathered from flowers and are used as food. The propolis is a resin or gum that is gathered from plant buds and other sources and is used to seal up cracks in the hive. Any animal,—such as a bumblebee or mouse which comes into the hive and is killed by the bees and can not be removed, is sealed over with propolis. Why is this done?

Wax is secreted in glands called "wax-pockets" on the under side of the abdomen. It is used for building comb in which to raise the brood and store honey and "beebread" which is a mixture of honey and pollen. The cells are of two sizes. In the large cells unfertilized eggs are laid, which develop into drones. In the small cells fertilized eggs are laid which develop into workers. An egg, in either case hatches into a legless, white grub called a *larva*. It is cared for by the young bees and in a few days becomes full

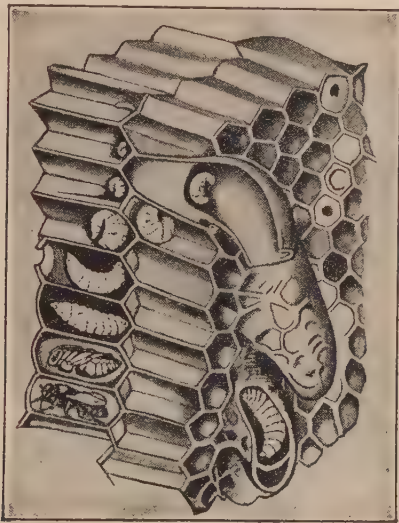


FIG. 15.—The life history of a honeybee. Worker bees are developing in the small cells. The large cells are queen cells. The bee has an indirect metamorphosis. The egg hatches into a larva, which grows, and becomes a pupa. When the skin is shed the last time, it becomes a bee. (*Benton.*)

grown when it is sealed over with a wax cap. In about 21 days the bee gnaws its way out fully developed. Under average conditions a drone emerges in about 25 days and a queen in about 16.

**Swarming** is the natural method of increasing the number of colonies, but in the *apiary* (bee farm) man has other methods of increasing the number of his hives. Two or three weeks before the bees are ready to swarm the queen lays eggs in a number of large cells

that have been prepared for raising queens. One of these eggs develops into a young queen which takes the place of the old one when she leaves with a swarm.

The bees usually choose fair weather for their swarming day. The old bees and queen emerge from the hive with a great buzzing and fly in great confusion in the vicinity of their hive. They soon cluster near by around their queen in a dense mass which is known as a *swarm*. If they are not hived within an hour or two they usually fly



FIG. 16.—An apparatus for hiving a swarm. Be able to describe how it is used. (*Root, A B C and X Y Z of Bee Culture.*)

away and cluster again at some distance. Finally, they find a hollow tree or some other cavity and start a new colony. The wild bees on this continent have escaped from bee-keepers. They are native to the Eastern Hemisphere.

There are many ways of capturing a swarm but probably the surest is to clip the wings of the queen so she can not fly. When the swarm comes out she will be found crawling around in front of the hive. The bees will cluster as usual but when they find their queen is not with them they return to the old stand. In the meantime an empty hive has been placed on the old stand, and the old hive removed.

When the bees return the queen is placed in the new hive with the returning bees, and the swarm is hived. If the keeper does not wish to increase the number of his colonies he may later kill the old queen and set the new hive on top of the old hive, and, thus, reunite the bees which now have a young queen.



FIG. 17.—An observation hive. These hives should be placed in a window with a south exposure. The side panels are removable, and beneath them are panes of glass through which the bees may be seen.

**Economic Importance.**—The bee-keepers of the United States produce annually more than \$22,000,000 worth of honey and wax, but millions of pounds of nectar remains ungathered in the fields because there are not enough bees to secure it. The number of hives could be increased many times over, if properly distributed, without crowding. Bees are very important pollinators of all kinds of fruit and berries and many kinds of other crops. Every orchardist should keep bees to insure proper pollination of his fruit blossoms. Every



high school and college should have an observation hive where the work of the bees may be watched by the students.

### OUTLINE-SUMMARY

The life of the bee is ruled by instinct and is a very high development of an instinctive social life. They gather nectar and pollen from flowers, and in so doing they pollinate the blossoms.

The life and work of the hive.

The rearing of the young, and swarming.

The economic importance of the honeybee.

**Review Questions.**—Make the best definition you can of habit, reason, instinct. How does the bee get pollen into its pollen baskets? Of what use is the honey sac? Of what value is the bee to the goldenrod? Of what value is the goldenrod to the bee? What are the duties of the workers? Of the drones? Of the queen? Of what value to bees is each of the following: honey, pollen, propolis, wax, beebread? How do bees swarm? Why do they swarm? How does the keeper capture a swarm? Discuss the economic importance of the honeybee.

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### STUDY 4. ADAPTATION AND ENVIRONMENT

**General Questions.**—Are all plants and animals well fitted to live in the places where they are found in abundance? What is meant by adaptation? What is environment? How do the following influence life: temperature, water, light, air, soil, food, shelter? Why does tropical life differ from life in our part of the world? What is the food cycle?



There are many different kinds of places on this earth where plants and animals may live. Even in a restricted environment like a pond living things may be found at the bottom, or at the surface of the water; in the mud near the shore, or out in the deeper water; on plants under water, or on plants above water; swimming free, or attached; and in other situations. In the millions of years that plants and animals have lived on the earth they have gradually adapted themselves to live in various situations, and in various relations to other living things. As conditions have changed, life forms have been compelled to change or disappear. The number of kinds of plants and animals living on the earth today is small compared to the number of those that have lived and perished. Within the recollection of man the mammoth, saber-toothed tiger, dodo, passenger pigeon, and many others have become extinct.

The ability of life to change its structure and habits to conform to a changing environment is known as *adaptation*.

In biology the word *environment* is used to signify the total conditions upon which the life of a plant or an animal depends. The special study of the relation of life to its environment is called *ecology*. Its real meaning is *the study of homes*.

In this study we shall try to classify under seven headings the most important elements which make up the environment. They are: 1. temperature, 2. water, 3. light, 4. air, 5. soil, 6. food, 7. shelter.

**Temperature.**—We have learned in geography that the earth may be divided into five zones or belts of varying temperature,—the two Arctic Zones, the two Temperate Zones, and the Torrid Zone. It is obvious that the temperature of a plant or an animal must be above that at which the fluids in it freeze, or it can not grow.

In the Torrid Zone there is no winter and the plants grow continually. There is no need of protection from cold. Temperature conditions there are the most favorable, and life is very abundant.

In the Temperate Zones there is a cold winter and a warm summer. This is especially true of the North Temperate Zone where the large land masses give great extremes of temperature. Life here must be able to withstand great seasonal extremes of heat and cold. The

summer is the season of growth and reproduction, and the winter is the season of rest and retreat.

Many of the birds migrate to a warmer climate in winter. Frogs, snakes, and turtles bury themselves in the earth or the mud of ponds. Woodchucks and chipmunks sleep in their dens. This winter rest is known as *hibernation*. Name as many animals as you can which



FIG. 18.—An elm tree in summer and in winter. Plants which live in the temperate zones must have special methods of surviving the cold winters.

hibernate. Many of the trees shed their leaves and cease to grow. Such trees are said to be *deciduous*. Name some trees which are and some which are not deciduous. Many plants die entirely and preserve the race through the winter by means of their seeds which survive the cold of winter and grow the next summer.

In the Arctic Zones it is cold all the time, but in the southern part of the North Arctic Zone there is a short time in the summer when

plants may grow. These plants must be able to blossom and ripen their seeds very quickly. The land animals are covered with a heavy coat of fur and either hibernate in winter or wander over extensive areas in search of food.

*Altitude* is another important factor in determining temperature. The tops of mountain ranges are cold, and life conditions here resemble those in arctic regions in many respects.

**Water.**—The bodies of plants and animals are composed largely of water. Life can not exist without it. Mention some of the ways in which water is of importance to animals.

Water exists in varying quantities in the air, and the amount that the air can hold depends upon the temperature. Warm air can contain more water vapor than cold air. When air containing water vapor is chilled, its ability to hold vapor is reduced. If more water vapor is present than can be held, it falls in the form of rain or snow.

Regions where the rainfall is not sufficient for a vigorous growth of vegetation are called *deserts*. Desert plants store up food and moisture during the rainy season and have few or no leaves. The plants of the genus *Yucca*, however, have thick, juicy leaves in which food is stored. These plants are "stemless" except when they are in blossom. When leaves are absent the stems are green and function as leaves. Food is stored in either the root, stem, or leaf. Animals of the desert generally wander extensively in search of food and do not require water as often as other animals do. Name some desert plants and animals and discuss their special adaptations for desert life.

*Rain water* either runs off from the surface of the earth to form streams, sinks into the ground to emerge again in the form of springs, or evaporates and returns to the air. A large part of it enters rivers and flows to the sea. Ocean water differs from that of most lakes in that it contains salt. The presence of salt has a great effect on life, and very few forms of plants or animals are able to inhabit both salt and fresh water.

Scientists believe that the first forms of life lived in the seas, and it is here that many of the simplest and most ancient forms are found today. The conditions of life in the oceans are believed to have

changed but little throughout the centuries, and this has permitted many primitive forms to remain undisturbed.

**Light.**—We shall see in another study how light is used by plants in the manufacture of their food and understand that without light there would be no green plant life. Since the animals are dependent

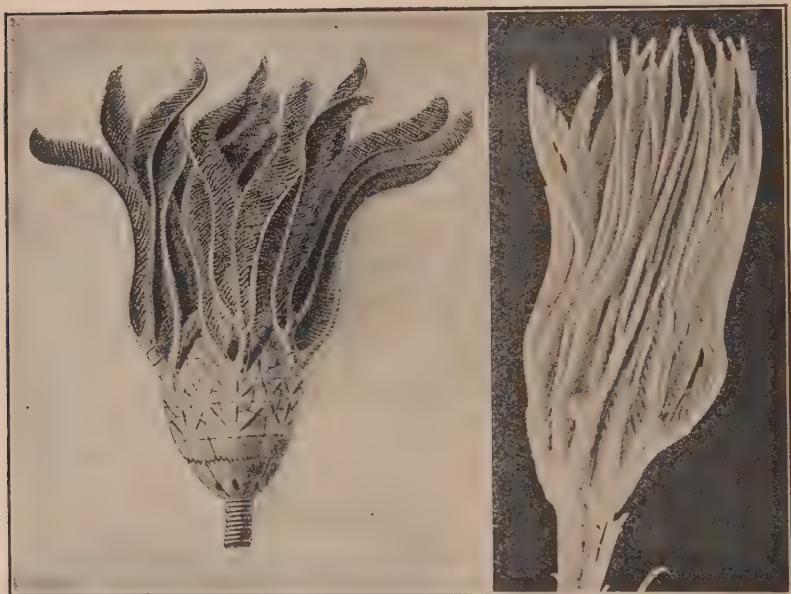


FIG. 19.—Two sea lilies. These are animals which are attached to the ocean bottom and, superficially, resemble plants. The one on the left lived many thousands of years ago when the ocean covered what is now the State of Tennessee. The one on the right is living in the ocean to-day. The change has not been great, because ocean conditions remain practically constant from age to age. The fossil is from a drawing by Prof. Troost.

upon the plants for their food they too would perish. Almost every one has noticed how the leaves of many plants adjust themselves so as to receive a maximum of sunlight. This turning of leaves toward light is known as *phototropism* (*Gr. phos* = light + *trope* = a turning). It is a very common phenomenon among plants which thrive in sunlight and shows the importance of sunlight to plants.

Animals respond to light largely through their sense of sight. Animals which take up a cave or underground life usually lose the use of their eyes and have other structures, such as feelers, very highly developed.



FIG. 20.—Two views of the same begonia plant. It was placed so that light struck it from only one side. Did it adjust its leaves so as to receive more or less light?

**Air.**—The composition of air is shown in the table.

COMPOSITION OF THE AIR

| Name of gas                   | Per cent of volume |
|-------------------------------|--------------------|
| Nitrogen.....                 | 76.95              |
| Oxygen.....                   | 20.61              |
| Argon.....                    | 1.00               |
| Carbon dioxide (average)..... | 0.03               |
| Water vapor (average).....    | 1.40               |
| Air.....                      | 100.00             |



Of these five gases oxygen, nitrogen, water vapor, and carbon dioxide are essential to the life of the earth. It is common knowledge that oxygen is essential for respiration in animals, but it is not so well known that plants respire also.

Plants get very little nitrogen from the air, but it is obtained in quantity from the soil.

The air takes up water vapor from the soil, from plants and animals, and from the surface of lakes and oceans and distributes it over

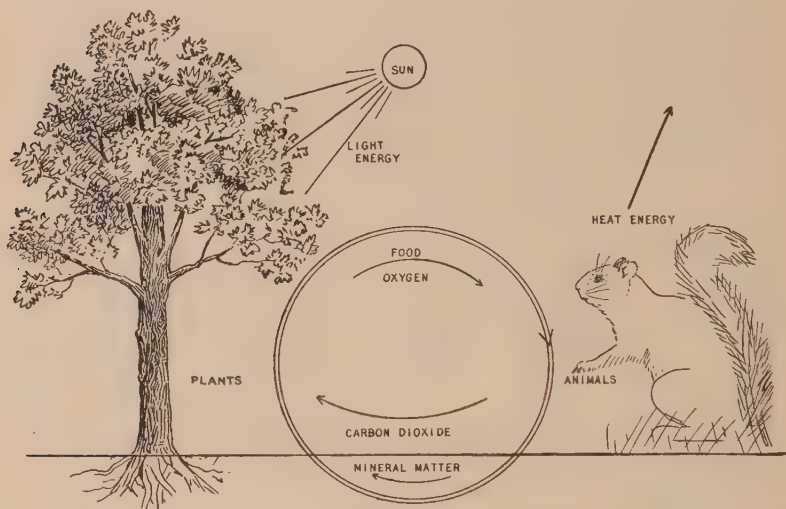


FIG. 21.—The food cycle. What does the squirrel get from the tree? The waste products of the squirrel's life are given back to the air and to the earth and may be used as food by the tree. What are these waste products?

the face of the earth. Thus the rainfall of a place is largely dependent upon the prevailing wind direction.

Although there is only a small amount of carbon dioxide in the air, it is very important because out of it plants make a great part of their food. This process will be discussed and studied later. The carbon dioxide of the air is of little, or no, direct importance to animals.

**Soil.**—Soil is of importance to plants in that they are anchored to it by their roots and that they get their water and mineral food from it. It is well known that a vigorous plant growth does not take place



on a poor soil. Animals are not apparently so dependent upon soil conditions as are plants, because their dependence is indirect. Soils will be more fully discussed later.

**Food.**—The food supply of plants is comparatively simple. They absorb simple substances from the soil and air, and in the presence of sunlight manufacture food from them. Thus plants build up food. Animals take in food that is already built up and oxidize it in their bodies and thus reduce it to simple substances again. This production of food by plants, and its destruction by animals, is known as the *food cycle*.

There is a great struggle in life for food. This is not always easily apparent, but it will be shown later on that the abundance of any plant or animal in a given locality is determined largely by the food supply.

**Shelter.**—Under this term are grouped all those characters of plants and animals which enable them to escape death from enemies or an unfavorable environment. The cactus has its thorns, the poison-ivy its poisonous juice, the jimson-weed its bad odor, and the fennel its bitter taste. The toad is colored to match its surroundings. The crayfish has its pinchers, the bee its sting, and the stag his horns. The rabbit is fleet of foot; the chipmunk retreats to its hole in the ground. The methods of seeking protection are various but they all tend to accomplish the same object which is the preservation of the individual and the race.

### SUMMARY

In this study we have outlined the main environmental factors which combine in different ways in different localities to make up the conditions in which plants and animals live. We shall find later on that life is always fitted or *adapted* to its environment. The cactus can not live in swamps nor can the water lily live in deserts, but each is fitted to live successfully in the place where it is found.

**Review Questions.**—Define environment, adaptation, ecology. Name the seven major factors of the environment. How does life in each of the three temperature zones differ? Define hibernation, deciduous, altitude. What are the special characteristics of desert plants? Compare the effect of light on plants

and animals. What gases of the air are important to life? Of what importance is each? How are plants related to the soil? Explain the food cycle. What is meant by shelter?

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### SUGGESTED STUDENT ACTIVITIES FOR UNIT II

**Club Organization.**—Organize a science or biology club in your school. Arrange for regular meetings. Appoint committees to carry out your business, projects, programs, museum organization, magazine subscriptions, and keeping of archives.

**Problem.**—Estimate the number of seeds produced by a single goldenrod plant. How many plants would there be in five generations if all seeds should grow? Are there any more plants on the earth one year than another? Discuss this matter in class.

**Suggested Project.**—Make a collection of all of the different kinds of insects which you can find visiting the goldenrod. With the aid of the teacher and books, learn their names, mount them in a permanent case, and put them in the school museum.

**Field Trip.**—The class should visit an apiary if possible.

**Suggested Project.**—If there is no observation hive in the laboratory, appoint a committee to investigate ways and means of securing one.

**Class Project.**—Make a list of all of the kinds of flowers which you see bees visiting. Which do they visit the most?

**Report.**—Some one may look up the life history of the bumble bee and compare it with that of the honeybee. Several species of bumble bees are native to North America.

Write to the U. S. Department of Agriculture, Washington, D. C. for their publications on the honeybee.

**Field Trip.**—If the vicinity of the school affords them, some of the features mentioned in the study of environment should be visited. Make a careful study, with definite assignments to various groups. Make the assignments before starting on the trip, and report from notes in class the day following. Is it necessary for all of the class to go to the same place? Can a group work successfully without the presence of the instructor?

**Reports.**—Let each student select a plant or animal and report on its method, or methods, of securing shelter.

### UNIT III. THE FOOD RELATIONS OF PLANTS, ANIMALS, AND MAN

Food is an essential to living things. It is the material out of which their bodies are built and from which they get the energy to carry on their lives. We shall learn how this food is obtained from the earth, what minerals and gases are used as the raw materials, and how these materials are made up into food.

Because of the great importance of food, plants and animals have many special adaptations for obtaining it and disposing of it after it is secured. Both plants and animals store food in times of plenty for use when it is not so easily obtained or when it is needed in great abundance. We shall be interested in these special structures and methods.

Because plants make all of the food of the world and animals get it from plants, we shall discuss the plant first. We shall want to fully understand its roots, stems, and leaves. Lastly, we shall study the food of man. What are good foods? Why are pure foods necessary to our health? How are they digested and assimilated? These are questions which we should be able to answer from the study of the following lessons.

## PROBLEM 1. OF WHAT VALUE TO PLANTS ARE ROOTS?

**General Questions.**—Are all roots alike? What kinds of roots are there? What is the structure of roots? What are the four most important uses of roots? What is osmosis and of what importance is it to plants?

In beginning our study of food we must start at the source. The plant takes up water, mineral matter, and carbon dioxide and makes food of these materials. The minerals and water come to the plant through its roots, and it is best to begin our studies with this structure. In the first place we will want to know what a root is and what kinds of roots there are. In other words we will begin by studying the classification of roots.

When a seed germinates it puts forth a long root. If this root remains as the chief root of the plant, it is called the *primary root*, and all other roots are called *secondary roots*. The corn plant has secondary roots which spring from above the ground and grow through the air to penetrate the soil. They are called *brace roots* and help to hold the plant erect.

If the first seed root is longer than its branches, as in the case of the carrot or most tree roots, it is called a *tap root*. Such roots penetrate the soil to great depths and are often fleshy and filled with food. Plants which possess them are often adapted to withstand drought by sending their roots deep enough to secure water in the driest weather. The roots of alfalfa and sweet clover are of this type.

If the roots are all long and slender, as in the grasses, they are called *fibrous roots*. These roots, as a rule, do not penetrate the ground so deeply as the tap roots. There are some notable exceptions, however,—such as the sand hill grasses and kaffir corn.

Either the tap roots or the fibrous roots may become swollen and contain stored food or water. Examples of this type are the beet, carrot, radish, sweet potato, dahlia, and asparagus fern. Such roots are said to be *fleshy*. (See Fig. 142.)

Roots may also be classified according to their length of life. Upon this basis plants are classified as *annuals*, *biennials*, or *peren-*



FIG. 22.

FIG. 22.—Growth of a weed seedling, the kinghead, to show the development of a primary tap root. (Oswald.)



FIG. 23.

FIG. 23.—A young plant of cive, a relative of the onion, to show the development of a fibrous root system. (Robbins.)

*nials*. An annual is a plant which completes its life in one season and dies, as the mustard and ragweed. A biennial is a plant which lives

during a part of two growing seasons,—as the beet or fall wheat. Such plants often store food in fleshy roots or stems the first season, and produce seed and die the second.

Trees are perennials and live to be many years old. Other perennials, like the goldenrod, die to the ground every winter but continue



FIG. 24. Brace roots of the corn stalk. Note how they grow out from above the ground and push the leaf bases aside to grow into the soil. Note also their large size.

to live below ground and shoot up in the spring year after year.

Many perennials and biennials, and a few annuals as well, exhibit a peculiar phenomenon known as *root pull*. These plants are usually of a type known as *rosette plants* and are “stemless”. Their leaves spread out on the ground like a rosette, and they apparently



have no stem. The dandelion and peppergrass are examples. This is because the central axis of the root contracts longitudinally and draws the stem down into the crown of the root as fast as it grows. These plants often send up a long stem the second season or later on



FIG. 25.—A rosette plant—the dandelion.

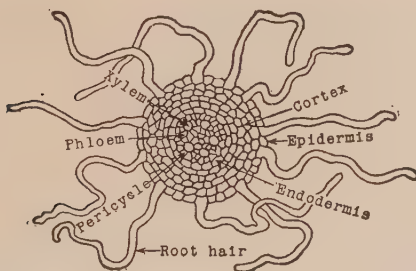


FIG. 26.—Cross section of a young root. About how much is the surface increased by the addition of the root hairs? Of what value is this increased surface? The central part is the stele. (Stevens.)

in the same season that the rosette is formed. It is obvious that it will be more difficult for a browsing animal to eat off a rosette plant than one which does not “hug the ground” so closely.

A cross section of a young root is shown in Fig. 26. It will be seen to be composed of three parts: the *epidermis*, the *cortex*, and the *stele*.

The **epidermis** is the outermost layer of cells and protects the inner parts. Some of the cells of the epidermis have long hair-like processes running out from them. These processes are called *root hairs* and come into direct contact with the soil particles. They are the absorbing organs of the root.

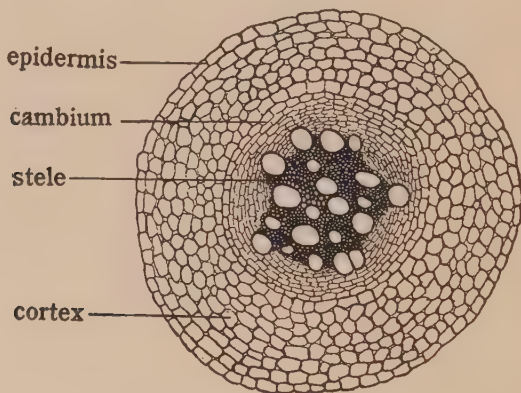


FIG. 27.—A cross section of a young root. (*Hamaker.*)

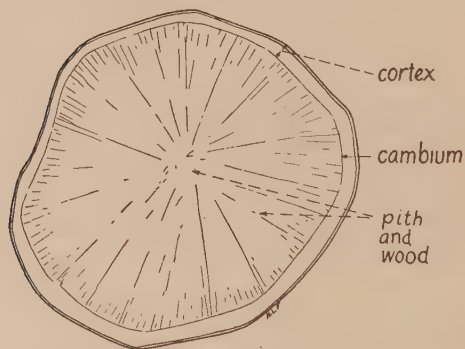


FIG. 28.—Diagrammatic cross section of turnip. (*Robbins.*)

The **cortex** is a thick region between the epidermis and the stele. It is prominent in fleshy roots and serves as a storehouse for food to be used later by the plant. Sap passes through it to the stele, traveling from cell to cell.

**The stele** is the central part of the root and is filled with fine tubes through which the sap passes. The woody tissue or *xylem* is the more central and carries the sap up to the plant. It is surrounded by *bast* or *phloëm* cells which carry sap down to feed the roots. We shall learn more about xylem and phloëm when we study the stem.

Now that we have outlined the types of roots, we are curious to know why there are so many different kinds, and what the various uses of roots are. Why do some plants have short, thick, roots and others long, slender ones? How does the work of these types differ?

These and other questions we must try to answer now. The four most important uses of roots are *anchorage*, *absorption*, *reproduction*, and *storage*. We shall consider each of these uses and think of the types of roots which are adapted to to do this work.

**Anchorage.**—One of the most conspicuous differences between plants and animals is that animals are free to move about while plants are anchored to one place. Try to pull a large weed out of the ground, and you will probably be surprised to note how firmly it is held in place. Browsing animals and severe storms would uproot many plants if it were not for this firm anchorage.

**Absorption.**—Pull up a plant and put the root in some red ink. In a short time the ink will be seen in the veins of the leaves. This illustrates the fact that water is being constantly taken up by the roots of plants and passed on to the leaves. Mineral matter which is contained in the soil water is thus carried to the leaves to be made into food. The root, it seems, is able to exercise some control over the kind and quantity of mineral salt that is absorbed, but only to a limited extent.

**Osmosis** is the name of the process by which roots take up water. It may be illustrated in the manner shown in Fig. 29. Sugar solution is placed inside the carrot, and water passes in faster than the sugar passes out. This causes the sugar solution to increase in volume and to pass up the glass tube. *If two solutions of crystalline substances, such as salt or sugar, of unequal density are separated by a permeable membrane, both liquids will pass through; but the less dense of the two will pass through the more rapidly. Protoplasm is not crystalline and does not pass through vegetable or animal membranes.* This is the law of osmosis and is the cause of sap pressure

in roots. The walls of the root hairs constitute the first membrane through which the soil water passes on its way to the plant. Acids

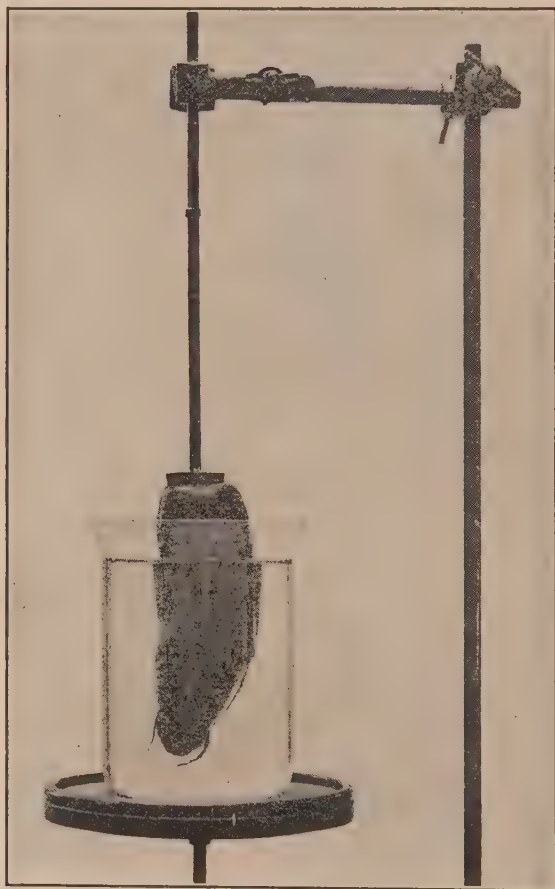


FIG. 29.—A carrot osmometer. Appoint committees to set up a few of these as a demonstration of osmosis for the class.

pass out through the root hairs and dissolve the soil particles, releasing plant food. No sugar is permitted to escape, however. This indicates that the living substance of the root is able to exercise

some control over that which passes out, as well as over what comes in.

**Reproduction and Storage.**—These uses are closely associated, and we will discuss them together. The fleshy roots of the dahlia



FIG. 30.

FIG. 30.—A pumpkin seedling with sand particles clinging to the root hairs. This shows how the root hairs come into close contact with the soil and obtain food matter from it.

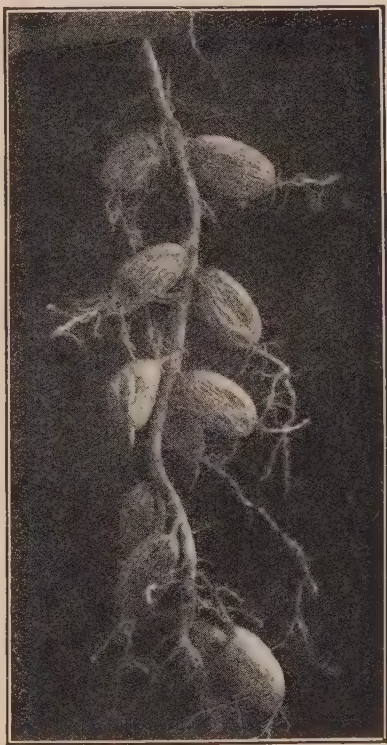


FIG. 31.

FIG. 31.—Fleshy roots of the fascicled type for water storage. These roots were placed in a drawer of the author's desk after the photograph was taken and remained succulent for six months before drying out. They are from the common asparagus fern. Can you secure one for the laboratory for experimental purposes?

and sweet potato contain much food which has been prepared by the leaves and stored over winter in the roots. This is a means of keeping



the plant alive over winter. Since there are several such roots on each plant, and each root may produce one or more plants the next summer, it is also a means of reproduction. Plants which live in deserts may store water in their roots to enable the plant to live through the season of drought.

The roots of cottonwoods, lilacs, and blackberries, when injured, send up shoots and may in time produce a great many plants growing in an association—all the offspring of one parent. Vegetables, like rhubarb, horse-radish, sweet potato, and asparagus are commonly propagated by planting portions of the root of a parent plant.

We are now in a position to understand how the root gathers many kinds of minerals and water from the soil, and by doing this work it makes its contribution to the life of the plant. In the studies which follow we will see what the food relations of the stem and leaves are.

### OUTLINE-SUMMARY

Classification of roots: primary or secondary, brace roots; tap roots, fibrous roots, fleshy roots.

Annual roots live one season, biennials live two seasons, and perennials live more than two seasons.

Rosette plants have very short stems and are said to be stemless while they are growing and storing food. They manifest root pull by the shrinkage of the stele of the root.

The parts to remember in the cross section of a young root are epidermis, cortex, stele, root hairs, bast, phloëm.

The four chief uses of roots are anchorage, absorption, reproduction, and storage. Osmosis is the process by which plants absorb their food from the soil and pass their fluids from cell to cell.

**Review Questions.**—Write out a table of the classification of roots. What are the special values of fleshy roots? Of what value are brace roots to corn? What advantages have plants with biennial roots? With perennial roots? What advantage have rosette plants? Draw a cross section of a young root and label all of its parts. How may we show that roots anchor plants in the ground? How may we show that they absorb water? Describe the process of osmosis. Name some plants which



reproduce themselves by their roots. Name some which store food in their roots over winter.

### SUGGESTED STUDENT ACTIVITIES

The teacher may call for volunteers to bring specimens of the following roots to the class: carrot, beet, radish, turnip, rhubarb, corn, grass, dandelion, alfalfa, sweet clover, kaffir corn, sweet potato, dahlia, mustard, ragweed, wheat, golden-rod, peppergrass, asparagus. Those which are secured may be studied and the special adaptations of each learned.

**Suggested Committee Projects.**—Evaporate such roots as the carrot and determine what per cent of them is water. Plant such roots as the apple, willow dahlia, sweet potato, beet and determine their ability to reproduce the plant. Test such roots as the radish, beet, turnip, and parsnip for the presence of fats, proteins, and carbohydrates. Always report on your projects to the entire class.

**Laboratory Work.**—Fleshy, tap, fascicled, and fibrous roots may be drawn in cross section and outline. Root hairs may be viewed under a magnifier and drawn. In doing laboratory work the student should have as few directions as possible. Each student should make his work show his individuality.

**Field Work.**—Pull up various weeds by tying the hook of a scale to them and noting the reading when the weed comes out of the ground. Bring the weeds and the record to class.

**Root hairs** may be obtained by placing a sprig of wandering jew in water about two weeks before the root hairs are to be seen. Another method is to make a *plate garden* by placing a piece of blotting paper between two glass plates and placing seeds between the paper and the glass. Keep moist until the seeds sprout. Radish, mustard, or turnip seeds are good.

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 Atwood, *Problems, Projects, and Experiments in Biology*, P. Blakiston's Son & Co.  
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 Payne, *Manual of Experimental Botany*, American Book Co.

### PROBLEM 2. WHAT ARE THE FOOD RELATIONS OF PLANTS TO SOIL?

**General Questions.**—How are plant roots dependent upon soils? What minerals are found in plants? Are these minerals found in all soils? Do plants grow equally well in all soils? What kinds of soils are there? Where does soil come from? How does water move through soil? What minerals are absent

**in poor soils? How may poor soils be improved? How may nitrogen be added to soils by bacteria?**

We all know that plant roots grow in soil, but do we know that some plants grow without soil? The green scum which floats on water in summer, is composed of several minute plants. Some plants grow on stone walls and on the limbs of trees. How do these plants live without soil, if it is so necessary?

One way to find out what the plant gets from the soil is to ask a chemist to test various plants to see of what they are composed. If the minerals which are found in plants are also found in the soil we may suspect that they are obtained by the plant roots from the earth. One way to obtain scientific knowledge is to suspect something, then to perform an experiment to test the idea. Chemists have determined that the following chemical elements are found in plants and are also found in soils:

|             |           |
|-------------|-----------|
| Oxygen      | Calcium   |
| Carbon      | Potassium |
| Hydrogen    | Sodium    |
| Nitrogen    | Iron      |
| Phosphorous | Silicon   |
| Sulphur     | Chlorine  |

By many careful experiments, chemists and biologists have learned that all of these elements are obtained from the soil, and that carbon and oxygen are also obtained from the air. We also know that all of these materials from the soil are taken in through the root hairs by osmosis, and that only those minerals which are in solution can be taken in by the plant. Some minerals such as aluminum, magnesium, manganese, iodine, and zinc may be found in the ashes of plants after chemists have burned them. Perhaps they were of no value, but were in the water which the plant took up and were taken up along with the valuable elements.

If we wish to learn which elements are necessary to plant life, we carefully prepare a soil which lacks the element in question. If the plant thrives in this soil, we conclude that the element is not necessary to the life of the plant; but if the plant languishes and dies, we conclude that the element is necessary to the life of the plant.

In this way we test certain soils to determine their fertility. It has been learned that plants will grow in almost any soil, but that some soils are short of phosphorous, potassium, or nitrogen. The other elements seem to be present, in nearly all soils, in abundant quantity. Furthermore, it has been learned that some plants take up more of one or more of these elements than other plants, and that if the same plant is grown on the same land year after year, one of these essential elements may be short, in which case the crop will not be thrifty. Such land is said to be "worn out", or *infertile*.

The problem, "*How can worn out soil be restored to fertility again?*" has been solved also by the simple process of discovering by chemical analysis of the soil what element is lacking, and supplying it.

**Fertilizers** are materials which are added to soils to restore some chemical which is deficient. These materials may be barn manure, guano, phosphate rock, green crops plowed under, and several commercial materials which are obtainable. Sometimes the soil is too acid, at which times lime is added to neutralize the acid, but there is always enough lime in soil for the needs of plants. It is said that lime "sweetens" the soil by reducing its acidity so that various beneficial bacteria may thrive there. These bacteria act in various ways upon the soil to release more of the potassium, phosphorous, and other elements from the solid sand particles for the use of the plants which the farmer raises.



FIG. 32.—The nodules on the roots of this pea plant are the homes of bacteria which gather nitrogen from the air. On older plants they are much larger.

**Nitrogen** is very scarce in the commercial world. The fertilizers which contain it are so expensive that it is sometimes a question whether it is profitable to use them, or go without them. Fortunately, it is possible to provide nitrogen for the crops in another way. Plants like peas, beans, and clover, which bear their seeds in pods, have little nodules containing bacteria growing on their roots (Fig. 32). These bacteria are able to extract nitrogen from the air and build it into salts which are given up to the plant roots on which they grow. Plants of this character are valuable soil enrichers where the supply of nitrogen is insufficient. In some of these plants this association has become so intimate that if the bacteria are not present, the plant on which they should grow can not live. For many years it was thought that alfalfa could not be grown in Illinois and Indiana. Scientists discovered that it was because the nitrifying bacteria were not present in the soils of these states. When the bacteria were placed in the soil, alfalfa grew excellently; and it is now a valuable crop throughout these states.

**Crop rotation** is a practice of alternating various crops with some crop which has nitrifying bacteria on its roots. This prevents the running out of the nitrogen of the soil. It is the custom to plant clover, or some other such plant, once every three or four years. When a proper crop rotation is in operation, it is necessary to replenish only the phosphorous and potassium as they are taken up and removed with the crops. This saves much of the expense of fertilizing land.

Let us now consider the differences in soils. You frequently hear it said that farmer Jones has *loam soil*, or that farmer Brown has *sand soil*, or that farmer Smith has a *light soil*. What do these expressions mean?

There are many forms and grades of soil, and most soils are complex mixtures of many types. There are, however, three classes of materials entering into the composition of soils which we may define. They are *sand*, *clay*, and *humus*.

**Sand.**—All soil was originally solid rock. This rock, upon being weathered, became soil. Sand results from the weathering of rocks containing quartz. Pure sand is composed of fine particles of quartz rock which have not yielded to chemical action and are

too hard to be reduced to a powder by the ordinary processes of weathering.

**Clay** differs from sand in that it is made from rocks of the feldspar type by the action of both chemical and physical agencies of weathering. The chemical composition of sand and quartz rock is the same, whereas the chemical composition of clay and feldspar rock is not the same. This chemical action reduces clay to a very fine grained condition. The carbon dioxide gas of the air, which is in solution in rain water, is one of the chief chemical agents in the formation of clay.

There are many rocks which can not be easily classified as quartz or feldspar. When these rocks weather the soil varies between sand and clay. Granite contains both quartz and feldspar and upon weathering forms a rich sand and clay soil. Limestone weathers readily under the action of water containing carbon dioxide. Much of the limestone is dissolved and carried away by the water, but that which remains forms a very fertile soil resembling clay.

**Humus.**—The third type of soil is formed by the decay of the bodies of plants and animals. It is black in color and very fertile. It is seldom found pure, but old lake beds which have been filled in by the growth of vegetation and then drained are nearly pure humus. Soils where plant growth has been abundant are rich in humus. Where plant growth has been limited, as in deserts, humus is not plentiful.

**Loam.**—Most soils are a mixture of sand, clay, and humus. Such soils are called *loam*. It is the universal soil mixture and varies with the proportions of the three types entering into its composition. When sand predominates the soil is said to be a *sandy loam*. When clay predominates it is said to be a *clay loam*. Sandy soils are said to be *light* because they work easily, and clay soils are said to be *heavy* because they are sticky and are worked with difficulty; but in reality a cubic foot of sand weighs more than a cubic foot of clay.

**Water.**—We have considered the fertility of soil, and how the root hairs get minerals from it for the plant, and how these elements must be in solution; but we have said nothing about water. Less than one half of the land in the United States is suited to agriculture.



Much of it is mountainous; much of it is swamp land. A considerable portion of our swamps can be drained. This land is usually a rich humus and very fertile. There are thousands of acres of semi-desert land in the West because the water supply is short. It is evident, then, that water is a very important factor in the relation of plants to soils. The water in good soil is said to be capillary water from the Latin word *capillus* which means a hair. It is so named because water will rise in glass tubes which are drawn out as fine as a hair.

**Capillary water** is not controlled by gravity but moves like the oil in a lamp wick and goes up as well as down. Its movement tends to



FIG. 33.—An experiment to demonstrate the use of a mulch. Place equal amounts of soil in both pans, wet them equally with water, and weigh. They should weigh equal. Place a weighed amount of sawdust on one pan and none on the other. Set them both away and weigh again from time to time. What effect does the sawdust have on evaporation?

keep all parts of the soil equally moist. Water is constantly rising from the lower layers of the soil to near the surface. In this way much of it is lost by evaporation. In our great plains states where the rainfall is not plentiful it is advisable to keep the upper part of the soil finely pulverized so that this capillary water will not pass through it and evaporate. This upper layer of fine soil is called a *mulch*, and the practice of keeping a mulch on the surface of the ground is called *dry land farming*. By this practice the productivity of dry soils is greatly increased. (See Fig. 33.)

#### OUTLINE-SUMMARY

Experiments have shown that at least twelve elements are found in plants and also in soils. We suspect that the plant gets its minerals from the soil, and chemical tests show that this is so.



Experiments show that some elements are short in some soils. These can be supplied by adding fertilizers. The materials which are so added are potassium, phosphorous, and nitrogen.

Nitrogen may be added to soils by rotating crops and planting clover, alfalfa, peas, beans, or some of their relatives which have bacteria in nodules on their roots.

Sand soil is made from quartz rock. Clay is made from feldspar, or some similar rock. Humus is made from decayed plant and animal material. Loam is a mixture of the three mentioned above.

Water is very necessary in soils; without it the land is a desert; with too much of it the land is a marsh or swamp.

Water moves in soil by capillarity. The practice of preventing the evaporation of soil water by the use of a mulch is known as dry land farming. It greatly increases the yields from land in dry regions.

Now we return to our original question, "Is soil necessary to plants?" The soil is not the essential thing; it is the water and minerals in the soil. Plants which grow without soil have special ways of obtaining these necessary chemical elements.

**Review Questions.**—Can plants grow without soil? How do we learn what minerals a plant contains? How do we learn which chemical elements are necessary to the lives of plants? How does a soil become infertile? How can it be restored? How may nitrogen be restored to the soil? Why do farmers practice crop rotation? Name the four classes of soils and tell how each is formed. How does water move through soil?

### SUGGESTED STUDENT ACTIVITIES

**Note to Teacher.**—Specimens of feldspar, quartz, limestone, granite, and peat should be secured and shown to the class when soils are studied.

**Committee Projects.**—Secure samples of various kinds of soils. Bottle them, label them, and put them in the museum case for future reference.

Carefully remove such plants as clover, alfalfa, and peas from the soil and bring them to class to demonstrate the presence of nitrogen forming bacteria in their nodules.

**Laboratory Work.**—Committees may be appointed to work up experiments on capillarity, percolation, the use of a mulch, presence of water in apparently dry soil, relative ability of soils to hold water, amount of organic matter in various soils, mechanical analysis of soil by means of sieves.

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## PROBLEM 3. OF WHAT VALUE ARE STEMS TO PLANTS?

**General Questions.**—If we cut into a plant stem, what do we find? How are its parts arranged? What is bark? What is wood? What are their uses? How do stems grow? What causes the rings in a tree stem? What are buds for? Are they all alike? What is the classification of stems? In what ways do stems climb? What advantages have stems which grow under ground?

The best way to gain an understanding of the stem and its value to the processes of food getting and growth of the plant is to study its structure. When we have learned this, we will try to understand the uses of each of the parts of a stem and the advantages of each kind of stem, for all stems are not alike.

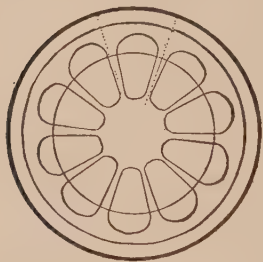


FIG. 34.—Diagram of a cross section of a young stem to show how it resembles the spokes and hub of a wheel in the arrangement of the parenchyma. The next figure shows an enlarged drawing of the part between the dotted lines. (Hamaker.)

If we study a cross section of a young stem under the microscope, or with the lantern, it will look like figure 35. Looking from the center of the stem we find three zones of tissue, namely *pith*, *wood*, and *bark*.

*Pith* is composed of large, thin walled cells known as *fundamental cells* or *parenchyma* (par-en'-kim-ah). This is the original tissue out of which the other tissues of the stem are made. Its arrangement in the stem is like the hub and spokes of a wheel. This is well shown in the small figure. The portions of pith which correspond to the spokes are called *medullary rays* (med'-ul-a-re).

**The cambium layer** which separates the wood from the bark is the region of growth in the stem, bark being formed on its outer side and wood on its inner. Which is produced in the greater abundance?

**Wood** contains, among others, three types of cells which are worthy of special mention. They are shown in Fig. 36 and are all developed from cambium. The *tracheal tubes* (A) are formed from a chain of cells by the breaking down of their end-cell-walls; thus a tube is composed of several cells. The *tracheids* (B) are

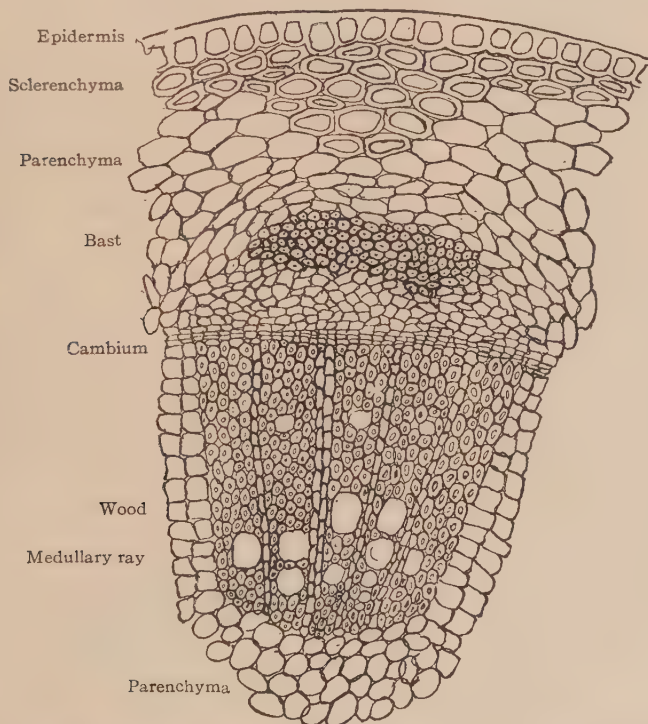


FIG. 35.—Diagram of a sector of a young stem to show the arrangement of the various types of cells. See the previous figure. (Hamaker.)

cells which have grown long and their ends have pushed past each other so that the end-cell-walls are diagonal and are pitted. Sap may pass through these pits from cell to cell. This gives the name *pitted tracheids* to these cells. They assist the tubes in the circulation of sap. The *wood-fiber-tracheids* (C) constitute the third type. They are like the pitted tracheids but have no pits and have thick

walls. Their function is to give strength to the tree rather than to carry sap. When each type is mature the protoplasm within dies, leaving the cell wall to remain as dead material. It is remarkable that all sap movement in plants, except that in growing tissues, is through dead cells.

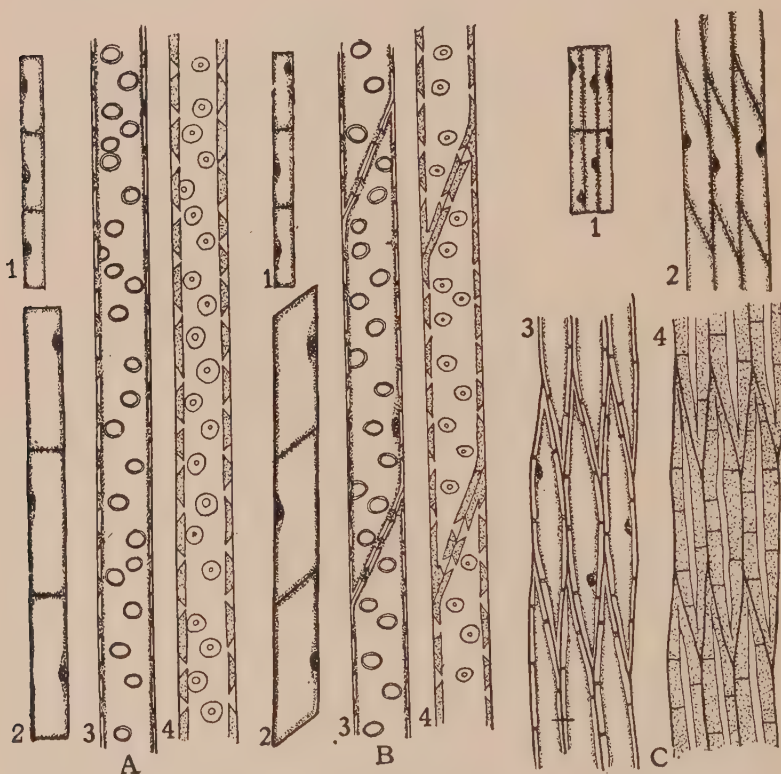


FIG. 36.—The development of a tracheal tube (A), a tracheid (B), and a wood fiber (C). The fundamental cells out of which each is made are shown in each case in 1. Note how they change to produce a tube in A, a row of hollow cells with slanting ends in B, and long tough cells in C. (Stevens.)

The bark contains *epidermal cells* in its outermost layer. These soon die and break up and are not found in old stems. Beneath these are the *cork cells*. Examine a piece of cork with a microscope.

In the inner region of the bark are the *bast fibers* which are somewhat like the woody tracheids, but are usually more slender. The *stone cells* (*sclerenchyma*) are tough-walled cells which give strength to the bark. Near the cambium ring are the *sieve tubes*. These are similar to the tracheal tubes, but the cross walls remain in place, and they are not so large nor are they so abundant. Many openings occur in the cross walls and this gives the tubes their name of sieve tubes. They are the avenues through which the sap of the bark flows down to the roots and other places, whilst the tracheal tubes and pitted tracheids of the wood carry sap up to the leaves. Why should the tube system of the wood be more extensive than that of the bark?

**Annual Rings.**—One of the most striking characteristics of tree stems is the series of rings (annual rings) which compose the wood. If these rings are examined closely they will be seen to be composed of alternate bands of large and small pores in the stems of the broad leaved trees, and of alternate bands of large and small wood fibers (tracheids) in the evergreens. The large pores and cells are formed in the spring and the small ones during the summer. These pores are the tracheal tubes which we have mentioned. As a rule they do not occur in evergreens (Fig. 37).

We recognize three types of annual rings as shown in the illustration. (1) The *ring porous* woods where the pores are alternately large and small, (2) the *diffuse porous* woods where the pores are about equal throughout the year but the tracheids are unequal, and (3) the wood of evergreens where the pores are absent and the rings are formed by an unequal growth of the tracheids.

**Classification of Buds and Branch Arrangement.**—Growth may be *determinate* or *indeterminate* according to whether the growing shoot forms a terminal bud and stops growing or grows until the frost kills it. The illustrations show the terminal bud of cottonwood and the form of branching resulting from the indeterminate growth of the sumach (Fig. 39). What effect has the presence or absence of a terminal bud on the form of the tree?

Buds which occur on the sides of the branch are known as *lateral buds*. They may be arranged *oppositely* as in the horse-chestnut shown in the figure, or *alternately* as shown in the cottonwood of the





FIG. 37.—Three types of annual rings. Ring porous wood of ailanthus above. Diffuse porous wood of sycamore in the middle. Cross section of redwood to show absence of pores in the evergreens below.



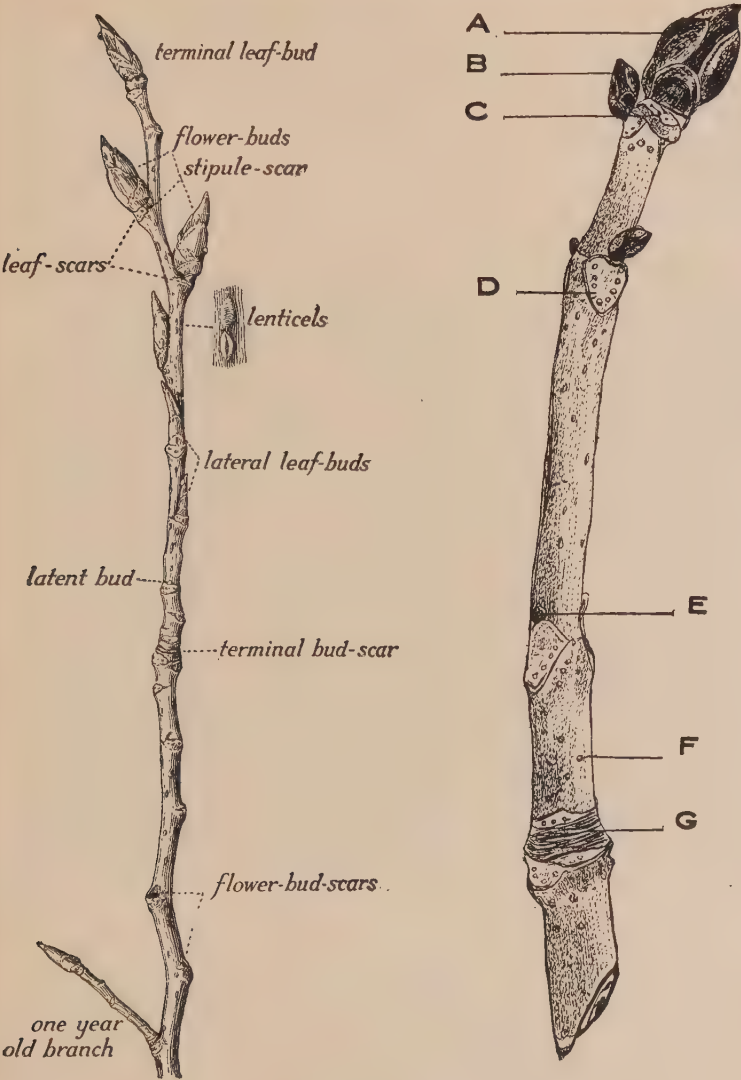


FIG. 38.—A twig of the cottonwood with its buds labeled on the left (*from Longyear*), and a twig of the horse-chestnut without labeling on the right (*original*). Be able to name each of the parts which is indicated by a line and letter. Compare with the labeled figure. Find out what lenticels are and what their function is.

same figure. Bud arrangement is dependent upon leaf arrangement, —the alternate buds being arranged in spirals, as are alternate leaves, around the stem. Opposite budded stems very seldom form terminal buds, and when they do (as in the lilac) they form a pair. Bring some branches to the laboratory which will show the type of growth resulting from the above mentioned bud arrangements. (See Fig. 38.)



FIG. 39.—Erratic branching of the sumach; due to the fact that it has an indeterminate annual growth.

Lateral buds may be of three types: (1) *axial*, in the axils of leaves; (2) *accessory*, when more than one bud is formed in the axil to provide for a second growth in case the main buds are caught and killed by an early frost; (3) *adventitious*, when they grow at any place along the stem not in the axils of leaves. Most plants can not produce adventitious buds; but elms, willows, and plums produce them readily. Of what advantage may they be?

**What is the relation of the plant stem to the rest of the plant?**

Stems may be divided into four classes according to the work they have to do: (1) erect, (2) climbing, (3) prostrate, (4) underground.

**I. ERECT STEMS.**—Most stems are of this class. The primary purpose for which the stem was developed in the plant kingdom was to lift the leaves above the green tissue of other plants and thus secure more sunlight. The first plants that lived on the earth had



FIG. 40.—An opening combination bud of hickory. Note the leaves unfolding, the flowers in the form of catkins, and the bud scales which are ready to fall off.

no stems. The development of fibrovascular tissue made it possible for sap to circulate easily, hence it became possible to have the leaves a considerable distance from the roots which supply them with moisture. The development of fibrovascular tissue for the circulation of sap, therefore, made the stem possible.

In the forest there is a quiet but intense struggle to secure sunlight. Those plants which fail in this struggle must have methods of living in the shade,—*i.e.*, become shade plants, or perish. Every oak tree

that grows to maturity in the forest does so by shading to death hundreds of other plants which contend with it for light (Fig. 41).

The stems of *herbs* are not woody and die in the fall of the year. Most herbs have given up the struggle to live in the woods and seek the open fields and fence rows, but some of them have acquired the ability to live with a small amount of light and cover the floor of the



FIG. 41.—An old pin oak tree, an example of an erect stem which survives the winter and begins growing where it left off the summer before. It is much more successful in obtaining sunlight than the grass and weeds which are its neighbors.

forest in spite of the shade. Many *saplings* (young trees) are able to grow in the shade of their elders for many years, waiting their opportunity to shoot up and spread their leaves in the sunlight.

II. CLIMBING STEMS.—Much food matter is required to build up the trunk of a tree. Some plants like the bamboo conserve much of this material by having long, hollow stems which are quickly and economically built up, but the vines have a still better way. They climb over other plants and thus are required to use more energy

in lengthening their stems and less in increasing their diameter. Vines are especially characteristic of the tropics, where they live

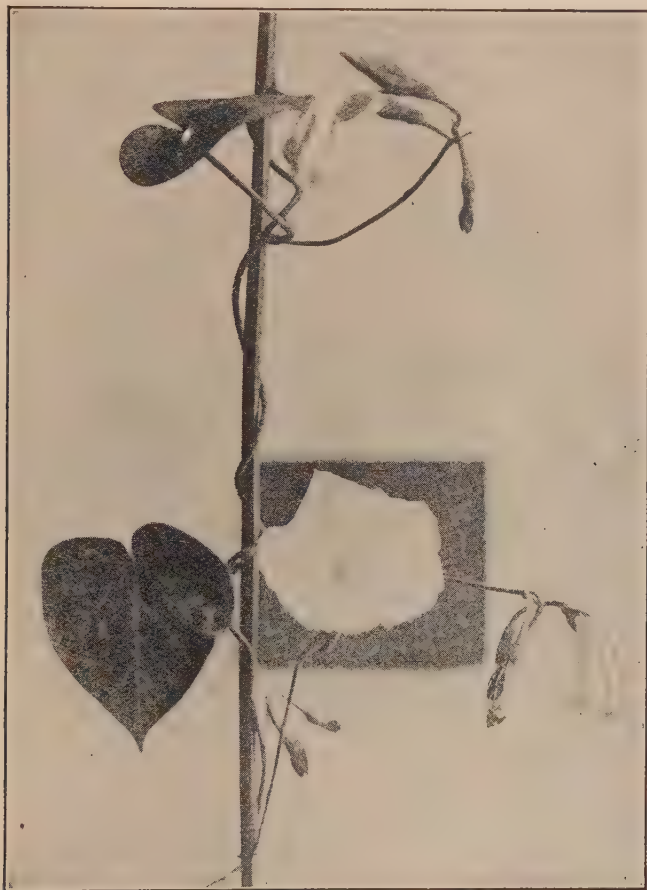


FIG. 42.—The morning-glory climbs by twining from left to right. The hop vine twines from right to left. Try to make a vine twine in the direction contrary to its nature. Report your results.

perennially and often kill the trees over which they grow. Many vines are annuals and grow as weeds or are cultivated in gardens.

Vines are of many kinds and belong to many different families of plants. Many of them have taken up the climbing habit independently, therefore it is not surprising that they should climb by various methods. We will discuss four types; (1) scramblers, (2) twiners, (3) tendril climbers, (4) root climbers.

1. **Scramblers** are the poorest of climbers. They have no special climbing structures, are usually thorny, and grow in a profuse sprawling mass. Examples are,—blackberries, dewberries, some kinds of asparagus, and the scambler (rambler) rose. (See Fig. 141.)



FIG. 43.—Disc tendrils of the Virginia creeper. These grow on the young shoots and are shown here holding the vine to a plastered wall. Later, on the older stems, climbing roots appear as shown in the next figure.

2. **Twiners** are very good climbers. They wrap around their support in a spiral curve. These vines are very slender and grow rapidly. The following are examples: morning-glories (Fig. 42), climbing beans, some honeysuckles, wild buckwheat, bindweed, and the hop vine.

3. **Tendril climbers** climb by modified leaves or stems. In the grape a branch which has lost most of the ordinary characteristics of branches coils around any small object which it touches. It then twists itself into a coiled spring and draws the vine up close to the



support. Some twiners are very sensitive. Those of the star or bur cucumber (*Sicyos*) will respond to a pressure equal to one eighth of the smallest amount that can be perceived by the most sensitive part of the human skin.

In the pea, part of the leaf functions in the normal way, but the tips of the veins of the leaves are modified to curl around the support. In the Virginia creeper, the tendrils terminate in flat discs which act as suckers. (See Fig. 43.) By this means it is able to climb up the bark of a tree or a brick wall. The gourd family (*Cucurbitaceæ*) including gourds, cucumbers, squashes, pumpkins, and melons comprises a well known group of tendril climbers.

4. **Root climbers** may be illustrated by the poison ivy, English ivy, and the trumpet creeper (*Tecoma*). Many small roots grow



FIG. 44.—The climbing roots of the Virginia creeper. On a field trip observe how they cling to the bark of trees and brick walls.

out all along the stem and fasten themselves to the rough surface of the support. (See Fig. 44.)

III. **PROSTRATE STEMS** are those that lie along the surface of the ground. These plants have apparently given up the struggle to ascend into the light and have become adapted to live in situations where this struggle is not necessary. It seems that they ignore the great prize that other plants strive for, but in losing this advantage they gain others. As they grow over the ground, roots are sent down from the joints in their stems, and thus they may spread rapidly. Many of their stems resist freezing in winter. They are not blown down by wind or easily eaten off by grazing

animals. They conserve the food and energy used by other plants for extensive stem building, and being close to the ground, and having many roots, their water supply is more easily maintained. White clover, strawberries, portulaca, dooryard knotweed (*Polygonum*), and



FIG. 45.—The rhizome of the cat-tail. Note the long white roots and the two buds which are to produce the plants of the next season.

many kinds of grasses have prostrate stems. Plants with prostrate stems are found growing on poor soil in abandoned fields, on sand beaches, along roadsides, on lawns, and in pastures. Many of them are persistent weeds, especially around dwellings and in barn yards.

IV. UNDERGROUND STEMS have completely abandoned the contest for sunlight and have become buried beneath the surface of the soil. Some of them, like the bracken fern, have delegated the work of elevating the leaf surface to the leaf-stem (*petiole*). Like the prostrate stems, the underground stems have apparently gained as much as they have lost by their peculiar habit of growth.

Underground stems may be classified, as rhizomes, tubers, corms, and bulbs. We have studied the **rhizome** of the goldenrod and noted

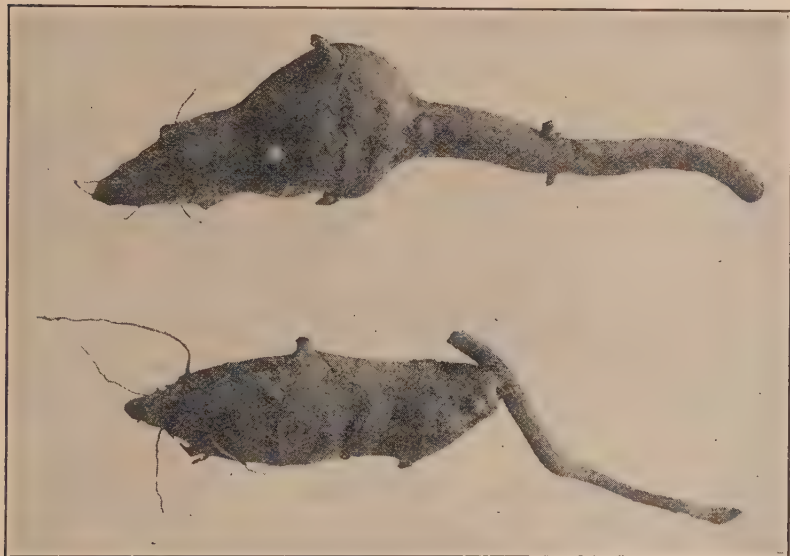


FIG. 46.—Two tubers of the artichoke. Note the eyes. They are buds, and the scales behind them are undeveloped leaves.

that it served as a means of maintaining the life of the plant through the winter and to multiply the number of plants in the spring. Plants like the blue flag, cat-tail, and water lily have very fleshy rhizomes and store considerable food in them. This food is available for the rapid production of foliage the next spring (Fig. 45).

A **tuber** is a special kind of rhizome where the food is stored at the end of the stem rather than all along it. The Irish potato is our best known example. (Sweet potatoes are not tubers but are fleshy roots.) (See Fig. 46.)

**The corm** is a hard, compact stem-base. The gladiolus, cyclamen, and Jack-in-the-pulpit are good examples of this type of underground stem (Fig. 145).

**A bulb** is really not a stem. It is composed of fleshy leaves clustered about a small stem. A bulb may be compared to a fleshy bud or a cabbage, ready to grow the next spring with vigor. Corms, tubers, and fleshy roots are often incorrectly called bulbs. The following plants have bulbs: onions, lilies, tulips, and the daffodil.

Make a table listing the advantages and disadvantages of the four classes of stems and discuss it in class.

### OUTLINE-SUMMARY

The three important parts of a cross section of a stem are the pith, wood, and bark. Fundamental cells are the cells from which all other tissues are built, and the cambium ring is the place of growth from which bark is made on the outside and wood on the inside.

Trees have annual rings which are caused by inequalities of growth in the cambium ring. They are of three types,—ring porous, diffuse porous, and tracheid rings of evergreens.

Classification of buds: alternate or opposite; axial, accessory, or adventitious.

Classification of stems:

| Erect | Climbing          | Prostrate | Underground |
|-------|-------------------|-----------|-------------|
| trees | scramblers        | vines     | rhizome     |
| herbs | twiners           | grass     | tuber       |
|       | tendrill climbers | weeds     | corm        |
|       | root climbers     |           | bulb        |

**Review Questions.**—Describe the parts which appear in the cross section of a young stem. How are fundamental cells related to all other cells? How is the cambium layer related to the wood and bark? How are annual rings formed? Describe each of the three types. How does sap circulate in a stem? Why does a tree die if the bark is removed? Can you identify each of the kinds of buds which we have studied if you see them on twigs? Name the four types of stems. Which lift leaves

into the light? Which live well over winter? Which store food well? Which help to reproduce the plant? How do plants climb? What great disadvantage have these plants? Can you identify each of the four types of underground stems from specimens?

### SUGGESTED STUDENT ACTIVITIES

**Field Trip.**—It may be convenient to make a trip for the purpose of studying stems, buds, and branches.

The names of the common trees and shrubs may be learned as a project, or on excursions. Is it worth while to know them? Why is it?

An attempt may be made to learn to recognize the common woods used in making furniture and in building, by their grain. This is usually a difficult study for some students.

**Laboratory Work.**—Lantern slides showing stem structure may be shown. Cross sections of stems may be viewed under the microscope. Count the rings in cross sections of woody stems to determine their age.

**Suggested Project.**—Make a collection of all of the types of stems mentioned in this study and preserve them properly in a museum case.

**Laboratory Work.**—Secure specimens of rhizomes, bulbs, corms, and tubers. Plant them in flower pots and appoint committees to care for them during the winter. They will add cheer and beauty to the department.

Place a branch of willow in water, top end down, and see if it will grow. In this case, which way is the sap flowing in the wood and bark? Place some red ink in the water and in about an hour cut the stem and see what parts are stained.

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### PROBLEM 4. HOW DOES THE FORM OF LEAVES VARY WITH THE WORK THEY DO?

**General Questions.**—What are the parts of a leaf? How are leaves classified? How are leaves arranged on the plant stem? How do leaves obtain more light? How does the air enter the leaf-blade? Why is it valuable to know the structure of leaves?



We must not forget that we are making this series of studies in order that we may understand the food relations of plants. The leaf has much to do with the manufacture of food for plants, and we must understand it as fully as possible. Our first inquiry is about the form of leaves. There are so many kinds, each peculiarly shaped to do its work in its own way, that we must make a scientific classification of them if we are to avoid being confused by their variety.

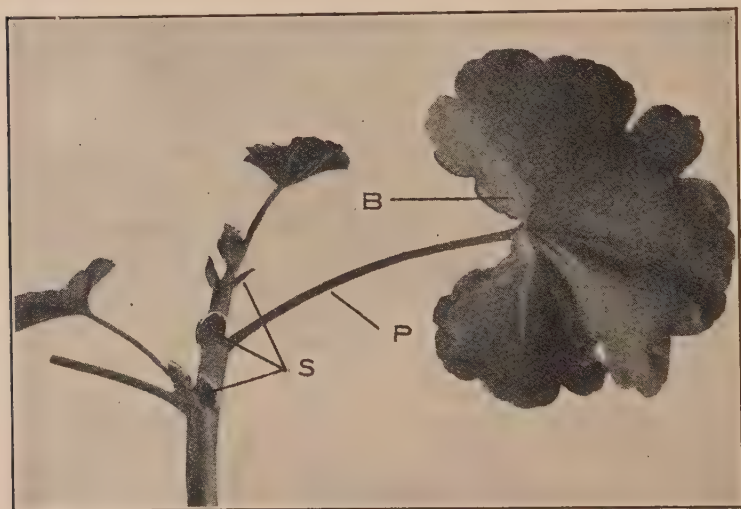


FIG. 47.—Geranium leaf, photographed to show the parts of a typical leaf. *B*, blade; *P*, petiole; *S*, stipules. Note the bud growing in the axil of the leaf just below the one which is labeled. This is the usual position for buds.

Their many forms are also so beautiful that we can not make this study without admiring their colors, designs, and arrangements. In the spring, it is the return of the green leaves of countless forms and sizes, coming forth by the millions, almost in a day, that tempts the school boy from his books and calls him out into the woods and fields. Nature is at her best when the hills and meadows are clothed with the fresh, green leaves of spring.

**The variety of leaves** is so great that they almost defy description. We can best approach the subject by examining a few common forms.



The geranium leaf is attached to the plant stalk by a long stem called the *petiole*. The leaf proper is called the *blade*. In the blade the

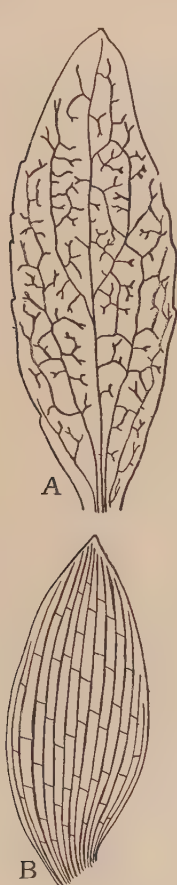


FIG. 48.



FIG. 49.

FIG. 48.—The two leaves on the left show net veining (above) and parallel veining (below). (*Stevens.*)

FIG. 49.—A leaf of the pea to show stipules, and the continuation of the midrib out of the leaf-blade to form a tendril. Is the pea leaf palmate or pinnate? Simple or compound? (*Robbins.*)

petiole is divided into many branches which form the skeleton of the leaf. These branches are called *veins*. In the geranium leaf there

are many of about the same size. In the bean leaf the divided petiole is continued as a main vein or *midrib* through each of the three parts of the leaf and branches are given off from the sides. Leaves like



FIG. 50.—Three types of palmately veined leaves. 1, geranium—simple palmate; 2, castor-oil plant—lobed palmate; 3, Virginia creeper—compound palmate.

those of the nasturtium, castor oil plant, and geranium are said to be *palmate veined*, because the veins run out as do the fingers from the palm of the hand. Leaves like those of the bean, apple, or fuchsia

are said to be *pinnate veined*, because their veins run out from a midrib like the barbs of a feather. Leaves of such plants as grass and corn have a midrib, but the smaller ones run parallel to it. Such leaves are said to be *parallel veined*. Pinnate and palmate veined leaves are said to be *net veined* because the small veins form a network.



FIG. 51.—Four pinnately veined leaves from the vegetable garden. The one on the left is of the *beet*, simple pinnate; the next is the *radish*, a lobed pinnate; the next is a *parsnip*, a compound pinnate; and the one on the right is a *carrot*, a doubly compound pinnate.

If we examine the leaf of the pea, rose, or locust tree we shall find that the side branches have become midribs of secondary leaves called *leaflets* which are arranged along the sides of the midrib. Such leaves are said to be *compound*. We may have *compound pinnate* or *compound palmate* leaves. Those just mentioned are compound pinnate. The horse chestnut leaf is a good example of a compound

palmate leaf. Compound leaves like those of the bean and clover are said to be *trifoliate*.

Attached to the base of the petiole of the leaf of the pea and geranium are two large, leafy structures called *stipules*. They are not found on all leaves. Examine a collection of various kinds of leaves in class and compare them with the types mentioned above.

**The veins of a leaf** carry sap to all of its parts. If we look at them closely, we will see that they leave the petiole as large trunks and break up into smaller and smaller tubes as they pass out into the leaf-blade. There are two distinct ways in which the veins of leaves are arranged. In the leaves of lilies and grasses the veins run parallel to the midrib and do not form a network; but in the leaves of the geranium and pea they branch irregularly. On this basis leaves, and the plants which bear them, may be classified as *parallel veined* or *net veined*. (See Fig. 48.)

**Leaves are arranged** on the plant stem in two ways. Those arranged as in the horse chestnut and elder are *opposite*. Those arranged as in the geranium are *alternate*. (See Fig. 52.) In the opposite class the leaves are arranged in pairs. Each leaf having its duplicate on the opposite side of the stem. In the alternate type they are single and ascend the stem in a spiral so that they do not set directly above each other. We have mentioned this opposite and alternate arrangement before when we studied stems. Buds develop where the leaves join the stem. This causes leaf arrangement and bud arrangement to correspond. Try to find several examples of each type and show them to your classmates in the laboratory.

**Leaves seek the light**, and it is the business of the petiole to place the leaf-blade in the most favorable light conditions. But there is still another important function for the petiole to perform. The leaf must be nourished, and some of the products of its activity must be returned to the roots. The petiole is the means of communication between the leaf and the rest of the plant. It contains much fibrovascular tissue through which the sap flows. Aside from serving as a skeleton for the support of the leaf-blade, the veins serve as collecting and distributing channels throughout the leaf tissue.

The leaf-blade is surrounded by a layer of flat, colorless cells. They constitute the epidermis and prevent the evaporation of mois-

ture, keep out dust and spores of parasitic plants, and, being very tough, prevent mechanical injury.

In the **epidermis** there are openings surrounded by kidney, or banana-shaped, cells which are capable of changing their shape so as to open or close the slit between them. These openings are called



FIG. 52.—Opposite and alternate leaf arrangement. Apple at the left and forsythia at the right. Note the stipules at the bases of the leaf-stems of the apple shoot.

*stomates* (Gr. *stoma* = mouth). Gases pass in and out through the stomates. In the leaves of the water lily the stomates are found on the upper surface only. In erect leaves they are found on both surfaces, and in horizontal leaves they are mostly confined to the lower surface. Can you give reasons for this? (See Fig. 105.)



The green tissue between the upper and lower epidermis is the *mesophyll* (měs'o-fil: Gr. *mesos* = middle + *phyllos* = leaf). The *palisade* cells lie next to the upper epidermis. They are shaped like columns or palisades and are set close together. Next to the lower epidermis is the *spongy* or *parenchyma* (parent) tissue. (See Fig. 53.) It is soft and composed of irregularly shaped cells set loosely together

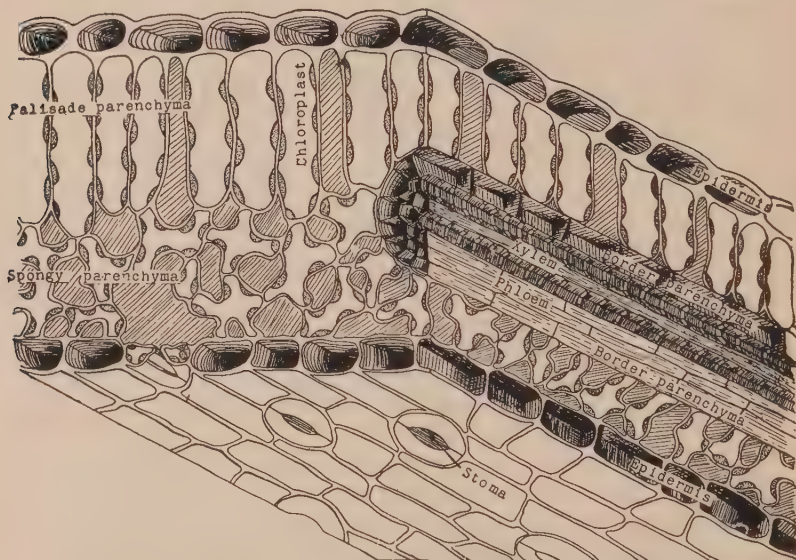


FIG. 53.—Stereogram of a leaf to show the tissues of which it is composed. Note the stomates in the lower epidermis, and the vein which is split lengthwise on the right. The tubes which carry sap to the leaf are labeled "xylem," and the tubes which carry sap away from the leaf are labeled "phloem." The air spaces are shaded. Note the palisade cells above and the spongy parenchyma in the lower side of the leaf. (Stevens.)

with air spaces between them called *intercellular* spaces. These spaces communicate with the stomates. We will take up the work of this green tissue in the next lesson.

### OUTLINE-SUMMARY

A typical leaf consists of a blade, petiole, midrib, veins, and sepals. The veining may be parallel or netted, and the arrangement of the veins may be palmate or pinnate.



Leaves are arranged alternately or opposite on the stem.

The petiole lifts the leaf-blade into the light.

A leaf is composed of epidermis on the outside, and fibrovascular bundles and mesophyll on the inside. The mesophyll appears as palisade tissue, and as parenchyma. The intercellular spaces within the leaf are filled with air.

**Review Questions.**—Why do we study leaves? Name the parts of a typical leaf. State the use of each part. Describe the arrangement of the veins of a leaf. Give some examples of compound leaves. Mention some leaves which have stipules. How are leaves arranged on the plant stem? How do leaves “seek the light”? What parts of the leaf carry sap? How does air enter and leave the leaf? Describe the green tissue of the leaf.

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Work.**—Make diagrammatic drawings of leaves to show parallel and net veining, pinnate and palmate veining, compound leaves, and various shapes of leaf-blades.

**Field Trips.**—Make collections of all of the kinds of leaves mentioned in this study. Draw some of them, press the perfect ones and put them, properly mounted, in a museum case.

**Individual Project.**—Can some one make a model of a cross section of a leaf? Use a mixture of salt and flour. It will dry hard and keep well. Mount it on a board and color it with water colors.

**Stomates** may be studied by carefully peeling the epidermis from the lower surface of various leaves and mounting in a drop of water under the compound microscope. An onion stem, the leaves of tulips and lilies, and the live-for-ever have an epidermis which is easily removed. Some leaves may be viewed as opaque objects, and if the light is just right, the stomates may be seen. Are there as many on the upper as on the lower sides of the leaves? Can you think of a reason for this variation? Compare leaves which stand erect with those which are held in a horizontal position on their stems.

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 Ganong, *Textbook of Botany for Colleges*, Macmillan Co.

## PROBLEM 5. HOW DO PLANTS MAKE AND USE FOOD?

**General Questions.**—Where do plants get the materials out of which they make their food? What part do roots, stems, and leaves play in the making of food? Can plants make food without sunlight? How is starch made? How are fats made? How are sugars made? What raw materials are necessary to make proteins? Do plants breathe? Do plants receive from their roots more water than they can use? Why can a plant which takes up much water grow faster than one which takes up little? How do plants get rid of their waste material? How and where do plants store their excess food? What use is made of stored food?

After reading the questions printed above, perhaps you think this is to be a difficult study. We have made very careful preparation to work out the answers to such questions. We have studied the soil because it is the source of water and mineral salts without which plants could not make food. We have studied roots because they collect these materials for the plant, and we studied stems so that we might know how food in the form of sap is transported from roots to leaves and back again. Lastly, we studied the structure of leaves, because leaves make food. They may be thought of as the factories of the plant. As we shall see, the air supplies carbon dioxide and oxygen to the plant. That these facts may be collected in one picture before the mind we have assembled them in a table below.

| Agent     | Importance                                      |
|-----------|-------------------------------------------------|
| Soil..... | Source of water and mineral matter.             |
| Root..... | Gathers water and mineral matter.               |
| Stem..... | Transports sap to leaves and to roots.          |
| Leaf..... | { Prepares food for the rest of the plant.      |
|           | { Throws off carbon dioxide, oxygen, and water. |
|           | { Receives carbon dioxide and oxygen.           |
| Air.....  | Source of carbon dioxide and oxygen.            |

### What work do leaves do?

We will discuss the work of leaves under four topics,—photosynthesis, assimilation, transpiration, and respiration.

**PHOTOSYNTHESIS.**—We have seen how the roots of plants take up water containing mineral salt and pass this material up to the parts above ground. This is the source of part of the food of plants. The greater part of the food of plants, however, comes from the air. (See Fig. 54.)

In the cells of the palisade and spongy tissue of the leaf there are small green bodies called *chloroplasts* (Gr. *chloros* = green + *plastos*

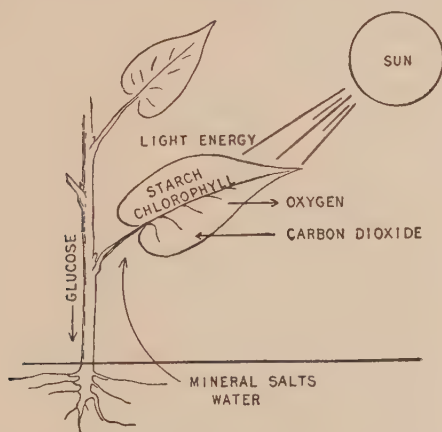


FIG. 54.—Diagram of photosynthesis. Study this diagram carefully and understand where the oxygen, carbon dioxide, and water come from and where they go. Note that the carbon on which the plant depends so much comes from the air and that a comparatively small amount of salt comes from the soil.

= molded). They can be seen in nearly any green, leaf tissue by the aid of the high power microscope. These bodies contain a green substance called *chlorophyll* (Gr. *chloros* = green + *phyllon* = leaf). This material contains the salts of iron linked with the protoplasm of the cell. It is insoluble in water but soluble in alcohol, and is capable of absorbing the energy of light and transforming it into chemical energy.

Excepting nervous tissue, chlorophyll is perhaps the most wonderful substance in living things. Without it all life on this earth

would disappear. All plant food is first organized in this material; and since the animal kingdom is dependent on the plant kingdom for food, the kind of life we have on earth would perish for lack of nourishment if it were not for the changes which go on in the presence of chlorophyll.

Carbon dioxide ( $\text{CO}_2$ ) gas exists in the air in very small quantity. It is taken into the leaf through the stomates, absorbed by the green cells, and broken up into carbon and oxygen. Carbon is combined with hydrogen and oxygen which are obtained by reducing the molecules of water ( $\text{H}_2\text{O}$ ) to the two gases of which they are composed. These three chemical elements,—hydrogen, oxygen, and carbon, are then combined to form molecules of starch.

Thus it will be seen that the raw materials out of which carbohydrates are made are water and carbon dioxide. In this process there is an excess of oxygen which is given back to the air. The amount of carbon in carbohydrates varies, but the hydrogen and oxygen are always in the same ratio to each other as they are in water, hence the name carbo + hydrate = carbon + water.

Usually chemical actions are attended by positive energy manifestations, *i.e.*, they give off light, heat, or electricity while they are going on. In the formation of starch, energy is absorbed. The energy which is absorbed in the formation of starch is the energy of sunlight transformed into chemical energy. Hence, unless the chloroplasts are receiving light they are incapable of making starch. *The process of making starch from carbon dioxide and water, in the green tissue of the plant, under the influence of sunlight, is called photosynthesis (Gr. phos = light + synthesis = composition).*

ASSIMILATION.—Under this heading we will discuss those changes by which the plant absorbs food and makes it a part of itself. The change from starch to sugar or cellulose is relatively simple since sugar and cellulose are carbohydrates having a chemical composition similar to that of starch. The form of sugar most commonly found in plants is *glucose*. It is made from starch in the chemical laboratory and sold as “corn sirup”.

Starch, as it exists in plants, is not soluble in cold water. Insoluble matter is not conveyed through plant tissue; and, hence, if it is to be moved from the leaf to the stem or root, it must be changed to

glucose which is soluble. In the sweet potato starch may be made in the leaf, changed to glucose and deposited in the root, where it is again changed to starch and stored until spring, when it is once more changed to glucose and used in building up the tissues of the young plant. Thus, we see that assimilation is not confined to the root. It may occur in any part of the plant.

*Carbohydrates, organic oils, and protein* constitute the three classes of plant foods and tissues. The *oils* contain carbon, hydrogen, and oxygen as do the carbohydrates and are made from them in the green tissue of the leaf and in other places in the plant.

Proteins contain carbon, hydrogen, and oxygen as do the carbohydrates and fats, and nitrogen and sulphur in addition. They often contain other mineral matter, such as potassium, phosphorous, and iron. Proteins can not be formed unless these elements from the soil are present. We are now able to understand why the soil is so essential to plant life. The living tissue of the plant, as distinguished from the wood and stored food, is composed of proteins organized into living protoplasm. Without the salts from the soil this protoplasm can not be formed.

### **How is food used by plants?**

The food of plants meets one of three fates: it may be *built into new tissue*; stored away in leaves, stems, roots, or seeds for future use; or it may be *oxidized* and used to release energy for the maintenance of the plant. In using the term "storage" we should not get the idea that the plant is in any way conscious of the future use to be made of this food.

The more rapidly a plant makes food the more rapidly it may grow. Vegetables in the garden grow vigorously, and as they do so food is stored in the parts which we eat. We have food stored in every part of the plant. In the natural course of events this food would be used by the plant at some future time in some way. Food stored in roots and stems may be saved until the next spring, or it may be accumulated early in the spring and used to produce seeds in summer.

Make a list of ten vegetables and be able to tell what the plant would do with the stored food in the part which we eat if it were not picked to be eaten by us.

Food which is not built into tissue or stored is oxidized. In this process energy is released for the use of the plant, but plants need very little energy because they have no muscles and do not move about. They do require energy for growth, seed production, and to hold their leaves in the most favorable position to receive light.

TRANSPIRATION.—We have already learned that the mineral food of the plant comes from the soil, is taken up in solution with water by the root hairs, and passed up to the leaves. This process is con-



FIG. 55.—Guttation drops on a tomato leaf. Try to obtain such drops by placing some young plant under a bell jar for a few hours.

stantly going on. The question which now arises is, "What becomes of all this water?" Much of it is used and retained in the plant, but there is an oversupply. The excess passes into the intercellular spaces and then out through the stomates in the form of water vapor. If the air is very moist it may not get out in this way fast enough. Under such circumstances the water passes out through *water pores*, which are modified stomates, and collects in drops on the edges of the leaves. This method of getting rid of excess water is called *guttation* (Fig. 55).



In transpiration much mineral matter which can not be assimilated is unavoidably brought to the leaves. Silica and lime accumulate in this way in considerable quantity. Dead leaves are heavily charged with mineral matter. Fall leaves are often bright red and yellow. This is partly due to accumulated mineral matter which they contain but mostly to the iron in the dead chlorophyll. The green color of leaves is due largely to iron which is contained in the

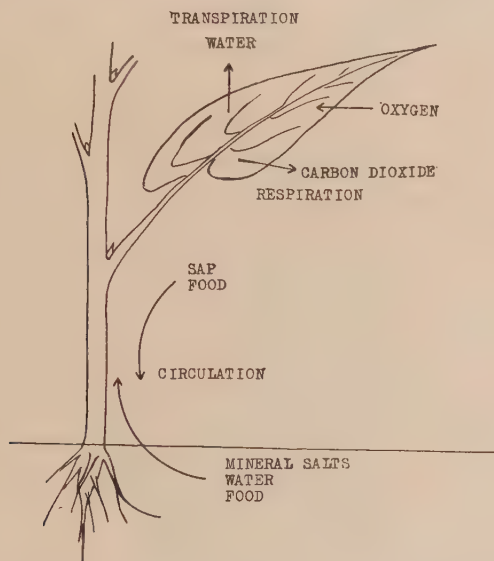


FIG. 56.—Diagram to show the circulation of sap from the roots to the leaves and back again. Transpiration and respiration in the leaf are also shown. These processes are different from those of photosynthesis. Compare this figure with the one to show photosynthesis on page 79.

protein of the chlorophyll. Iron forms two kinds of salts, the one kind being green and the other red. When the green salts are oxidized they become red or brown. It is believed that the beautiful colors of autumn leaves are caused by the oxidation of the iron in the green leaf tissue.

**RESPIRATION.**—It is common knowledge that animals breathe or respire. It is not so well known that respiration takes place in

plants also. The gases which pass in and out do so by *diffusion*,—*i.e.*, a free mingling of the gases inside the leaf with those outside due to the natural movement of the molecules of the gas. In photosynthesis we have seen how carbon dioxide is absorbed and oxygen is given off. In respiration this interchange is reversed. Oxygen

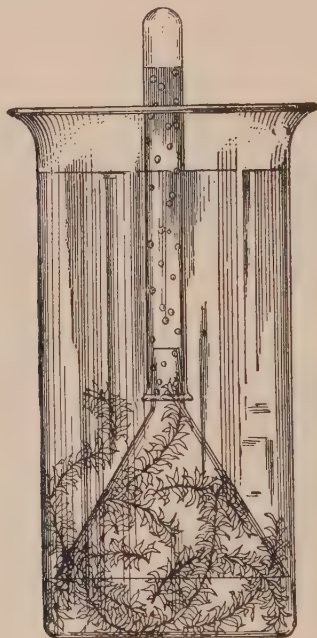


FIG. 57.—Apparatus for showing that oxygen is a by product of photosynthesis.

Oxygen will not collect in the tube unless there is carbon dioxide in the water in solution. The simplest way to replenish the supply is to blow the breath through the water frequently by means of a glass tube. Another way is to place several goldfish in the water. Their respiration adds carbon dioxide to the water. The jar must stand in bright sunlight. (*Livingston.*)

is absorbed and carbon dioxide is given off. Although the plant has no nervous or muscular system, it is an active, living thing. It grows, circulates sap, and responds to heat, light, gravity, and moisture conditions. These activities require energy for their performance. This energy is obtained by oxidation of food substances

and results in the liberation of water and carbon dioxide gas. The interchange of gases which takes place through the stomates is shown in the table below.

| Process             | Gases absorbed | Gases liberated                   |
|---------------------|----------------|-----------------------------------|
| Photosynthesis..... | carbon dioxide | oxygen                            |
| Respiration.....    | oxygen         | carbon dioxide and<br>water vapor |
| Transpiration.....  | none           | water vapor                       |

### OUTLINE-SUMMARY

Leaves make food by the process of photosynthesis in which carbon dioxide and water are combined to make starch. The energy used in this process is the energy of sunlight.

After being prepared by the leaves, foods may be assimilated by any part of the plant. Starting with carbohydrates, plants may organize any of the three classes of foods. Protoplasm can not be made unless certain mineral salts are present.

Food is used in growth, production of seed, building new tissue, for storage, and is oxidized to release energy for the operation of the activities of the plant.

Excess water is sent off by transpiration in the form of vapor from the stomates or as guttation drops which hang from the edges of the leaves.

In respiration, plants get rid of excess carbon dioxide as well as obtain oxygen.

**Review Questions.**—What do plants obtain from the soil? From the air? In food making, what is the value of roots, stems, leaves? Describe the process of photosynthesis. What is meant by assimilation? How is glucose made from starch? What elements may proteins contain which are not in starch? What do plants do with the food which they make? How do plants throw off the water which they do not need? How do they get rid of the minerals which they do not need? What

causes leaves to be brightly colored in autumn? Why do we say that plants breathe by diffusion?

### SUGGESTED STUDENT ACTIVITIES

**Demonstration.**—Set up the apparatus shown in the illustration and collect oxygen in the test tube which is placed over the funnel. Common ditch moss (*Elodea*) or some other plant which lives in water will do. This experiment does not work as easily as some manuals would lead the experimenter to believe. It must be in bright sunlight, and when the carbon dioxide in the water is all gone it must be given time to collect from the air, or it may be made from limestone and acid and bubbled in. How is this experiment related to photosynthesis?

**Laboratory Projects.**—Place a plant in total darkness and note how long it takes to lose its green color. Try more than one species. Do they all respond the same?

Obtain guttation drops by placing a young plant under a bell jar.

Seal a plant in a flower pot by covering the pot with rubber sheeting or paraffin so that all water must escape through the leaves. Keep a record of the loss in weight day by day.

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### PROBLEM 6. HOW DO FUNGI GET THEIR FOOD?

**General Questions.**—Are all plants green? What are fungi? Where are they found? How do they grow? How do they get their food? Why does food spoil? How may we prevent food from spoiling? How do we can food? What are ptomaines?

We have seen how green plants make food and use it in their life processes, but we have not mentioned that more than one-fourth of all of the species of plants do not have chlorophyll in any part of their bodies. These plants are known as *fungi* (fŭn' jī) a word which is derived from the Latin and means a mushroom. After learning about the wonderful method of making food which has been developed by the green plants, we naturally want to know how these plants, which have no green tissues, get along. Surely they do not

live without food. That would be impossible. Then is there some other way of making food? No, the only way by which food may be made is by green plants growing in the light.

Fungi live wherever there is food and wherever the conditions of the environment permit growth. Since food is always present where they are found, they need not make it themselves. They simply take up whatever they need from the place where they grow. We have seen how roots take up water by osmosis. Fungi gather their food by osmosis also. For this reason they can not grow on dry food, but wherever there is moisture and sufficient warmth they may be found.

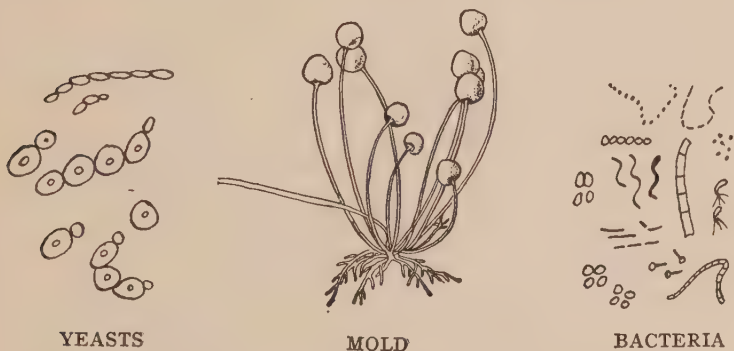


FIG. 58.—Three groups of fungus plants. (*Mold is from Gager.*)

When plants and animals die the food of their bodies is available for fungi. Logs decay, bread molds, milk sours, fruits ferment, and so in one way or another, all things are destroyed when they die. If this were not so the woods would be full of logs, leaves, and branches. There would be no humus in the soil, and all things which have lived would be preserved very much as they were when they died.

There are three kinds of fungi which are of great importance in decay. They are *yeasts*, *molds*, and *bacteria*. We will give a brief description of the activities of each of these.

**Yeasts** are single cells which are found in chains, or singly, wherever fruit juices or sugars are fermenting. They absorb the liquids in which they live by osmosis, and give off a peculiar chemical material

called an *enzyme* (ěn'zīm) which means yeast. There are many kinds of yeast, and many kinds of enzymes. The peculiar thing about them chemically is that they cause chemical changes to take place in sugar but are not consumed themselves. A quantity of enzymes may keep on working as long as there is sugar to work on. These enzymes change sugar to alcohol and carbon dioxide. In the distilling industry yeast is used to produce alcohol. In the baking industry it is used to produce carbon dioxide which is held in the dough making it rise.

**Molds** are of very little value to us. We are all familiar with them and recognize the musty odor which comes from things on which they have been growing. One of their chief characteristics is that they produce millions of small reproductive bodies called *spores*. These may be black, yellow, blue, or green. Molds are commonly known by the color of their spores, and are called green mold, or black mold accordingly.

**Bacteria** are of many kinds. They may live on either dead or living material. Wherever they may grow, they destroy that on which they live. If they grow among dead leaves and straw, they are beneficial, because it is by the action of bacteria that humus is added to soil. Yeasts and molds may also assist in this work. If bacteria grow in our food, they spoil it; but their presence may be desirable in making some kinds of cheese, souring milk, and making sauerkraut. Some of our most dreaded diseases are caused by bacteria.

**Mushrooms** are yet another kind of fungus plant in which we are interested. Our chief interest in them is that they are good to eat (Fig. 59). They grow on logs, tree roots, buried trash, sawdust, manure, and in fields where there is considerable decaying humus. We will discuss them in a future study, and will say no more about them now.

**How do yeasts, molds, and bacteria interfere with the preservation of food?**

All food, whether it is meat, fish, grain, fruits, or vegetables, must be cared for by special methods to preserve it from the time it is prepared until it is consumed. Bacteria, yeasts, and the spores of molds are everywhere. The conditions favorable to their



growth are the presence of food, warmth, and moisture. They are in no way dependent upon sunlight as are the green plants, and because of the great number and small size of their spores they penetrate to all places which are not sealed air tight. Wherever conditions favor their growth they appear.

**Drying.**—Some of the methods of preserving food are as old as civilization. The ancient people dried their grain, and stored it in

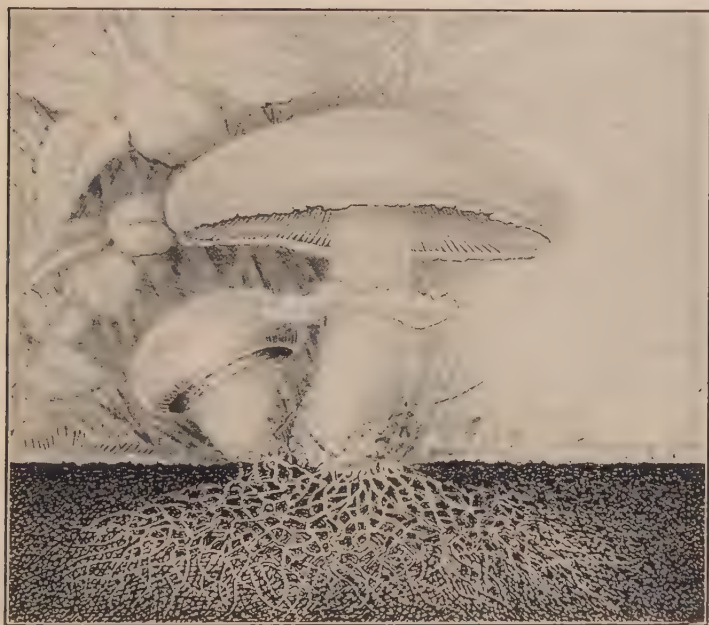


FIG. 59.—The common edible mushroom. The soil is shown as if cut away to show the part which gathers food. (Jenkins.)

bins. The American Indian dried buffalo meat. This is one of the safest and simplest methods of preserving food from spoiling, for bacteria can not grow where there is no moisture; and *unless the fungus plants grow in food it will keep forever*. They are the sole agents of decay.

In modern times meats and fish are dried and smoked. Apples, peaches, and Logan berries are evaporated in special ovens made for the purpose. Prunes and raisins are dried in the sun.

**Salting** is another simple and ancient method of preserving food. Bacteria can not live in strong salt solution, nor can they live in meat that is partially dried and thoroughly salted. Salting is still extensively used for preserving fish and meat. Beans and pickles may be canned by placing them in strong brine. Sauerkraut is made by placing salt on cabbage, but not enough to prevent fermentation. The acid formed by the fermentation together with the salt finally stops the bacterial action, and the product is ready for use.

**Acid** stops or prevents bacterial action if it is strong enough. Some acids, such as benzoic and salicylic are very fatal to fungi but may be eaten by man and animals in considerable quantities. However, their use should not be encouraged as they are at least slightly harmful to some people. They do not affect everyone exactly alike. The salts of these acids are also food preservatives. This indicates that their preserving qualities are not due to their acidity but to their chemical nature, which is to kill the protoplasm of the lower organisms.

*Vinegar* is made by allowing fruit juice or glucose to ferment. The sugar changes to alcohol under the action of yeast, and finally by taking on more oxygen and losing water, it changes to acetic acid.

The change to vinegar is accomplished by a fungus called *mother of vinegar* (*Micoderma aceti*). It may be found as a felt-like mat in the bottom of the vinegar jug. Examine it under the microscope. When fermentation has progressed to a certain stage no more action takes place because of the acidity of the liquid. Vinegar is used in preserving sauces, pickles, beets, and spiced fruits.

*Rhubarb* contains so much acid that if it is cut up, packed in a can, covered with water, and sealed, it will keep without cooking. Ensilage is preserved by the acid which forms when the sugar in the corn stalk ferments. Material which contains no sugar will not keep in a silo. Why must clover, alfalfa, and soy beans be mixed with corn when they are put in a silo?

**Sugar** in a concentrated form is a good preservative of food. Karo syrup, molasses, and maple syrup do not ferment if they are boiled down. Fruits are often boiled in syrup and thus preserved;

or dried fruits may be "sugared". Raisins, dates, and figs are examples. They contain enough sugar to preserve themselves when dry.

Sugar and salt kill bacteria by extracting the water from them by osmosis. This explains why they must be in a concentrated form.

**Sterilization** consists in killing all bacteria and their spores which may be present in the material to be preserved or in the retainers in which it is put. It is usually done by heat. No bacteria can stand boiling for very long. If the work is done under steam pressure it is more thorough, and a shorter time is required to kill the spores.

The cold pack method of canning fruit consists in putting cold fruit in jars, sealing them; then heating in boiling water, or preferably in a pressure cooker, until all bacteria are killed. In canning fruit or other material, if no bacteria or mold spores get into the can or under the cover, and if all that are present are killed by boiling, the fruit will keep forever. Sugar is not necessary in canning fruit, but if the work has been carelessly done the syrup may help to kill bacteria which have not been destroyed, or those that may enter later.

**Pasteurization** is a method of preserving milk. The process gets its name from the great French bacteriologist, Louis Pasteur. It consists in heating the milk to  $170^{\circ}\text{F}$ . for from ten to thirty minutes. If the milk is heated more than this it will change chemically and taste like boiled milk. This temperature is sufficient to kill all disease producing bacteria. Milk so treated is not only safe, but it will keep longer. Why?

**Refrigeration** consists in preventing the growth of bacteria by cold. At temperatures around the freezing point of water fungi do not grow. If their growth is prevented, no matter how numerous they may be, the food will remain as it is. The flesh of the extinct mam-

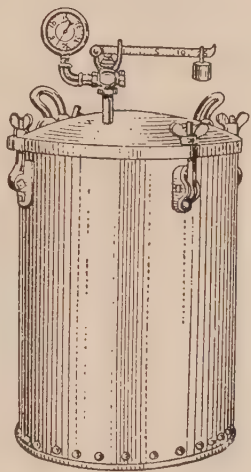


FIG. 60.—A steam pressure canner.



FIG. 61.—A series of twelve pictures illustrating the single period cold-pack method of canning fruit. Be able to tell just what is done in each picture. The third picture shows how a bag may be substituted for the wire basket.

moth of Alaska and Siberia has been found in ice perfectly preserved after being dead hundreds of years, and has been eaten by man and dogs.

Meats are frozen and packed for shipment on ocean steamers which have refrigeration plants on board. All sorts of perishable food may be kept in cold storage plants where the temperature is just above the freezing point. The refrigerator and thermos bottle are valuable inventions with which we are all familiar. In the refrigerator the temperature is usually several degrees above freezing, and bacteria do grow there, but not so rapidly as they would in the warm air of the pantry.

**Ptomaines** (tō'ma-īns) are poisons which are given off by certain bacteria which live in foods that contain much protein material. They cause serious intestinal trouble in man, and in some cases may cause death. Much of the indigestion which we suffer in the summer is caused by eating food which has partly spoiled and contains ptomaine poisons. Cooking may kill the bacteria, but it has no effect on the chemical composition of the poison. Hence, people are in as much danger from eating cooked food which contains ptomaines as they are in eating it raw. There is no good simple test which can be made to detect these poisons, and, for this reason, we should be all the more sure that we do not eat any food which has partly spoiled.

**Suggestion.**—Some practical work may be done in this subject by coöperating with the domestic science department.

### OUTLINE-SUMMARY

Not all plants are green. Those without chlorophyll are called fungi. They do not make their own food.

Three kinds of fungi which cause decay are yeasts, molds, and bacteria. Mushrooms also cause decay, but we will consider them later.

Food may be preserved by drying, salting, preserving in acid, sugaring, sterilizing, pasteurizing, and refrigerating.

Ptomaines are poisons which are produced by the growth of some kinds of bacteria in food. They are not removed by cooking.

**Review Questions.**—How do fungi differ from green plants in their method of getting food? Where do fungi live? On what do yeasts live? What do enzymes do? How can you tell if



molds are growing in food? Mention some ways in which bacteria are helpful. Some in which they are harmful. Why does food keep when it is dried? Why does salting and sugaring food keep it? Why does food keep in vinegar? How do we sterilize food? How do we pasteurize food? How does refrigeration keep food? How do ptomaines get into food?

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### PROBLEM 7. HOW DO ANIMALS GET THEIR FOOD?

**General Questions.**—How does the food getting of animals compare with that of green plants and fungi? In what way are euglenæ like both plants and animals. How do animals which do not move about get their food? What is the food cycle? How do plants and animals live in a balanced aquarium?

The methods of obtaining food constitute the most constant difference between plants and animals. We have seen how plants take in mineral salts and water through their roots by osmosis, and how they absorb carbon dioxide from the air and organize these three substances,—salt, water, and carbon dioxide, into food. This, of course, can be done only by green plants. We have also seen how the fungus plants, such as bacteria, molds, and mushrooms, are not green, and, hence, absorb no carbon dioxide for starch making. Therefore, they are compelled to live where they can absorb carbon, hydrogen, and oxygen in an organized form,—*i.e.*, in the form of carbohydrate, fat, or protein. These foods are taken up by osmosis much as green plants take up salt. *The essential thing about plants is that they do not take into their bodies organized, solid food to be digested.*

**Animals** do not have chlorophyll and, hence, can not make their food from mineral salt, water, and carbon dioxide; nor do they absorb water and minerals as do plants. Furthermore, animals are not



capable of absorbing the energy of light and using it in food building. In other words, *animals can not live on air, water, and soil as can plants.*

**Euglena.**—You may find floating on the surface of ponds in summer a small, green creature often called a plant by botanists and an animal by zoologists, because it feeds like a plant and also like an animal. It belongs to the genus *Euglena* and is composed of a single cell. It can contract like a ball or stretch out like a rod. At one end is a long lash which vibrates in the water and pulls the euglena along. Near the base of the lash is a “mouth” through which small particles of food,—such as bacteria are taken in. These particles are surrounded by a fluid which digests them, and they become a part of the euglena. Indigestible matter is cast out through the cell wall.



FIG. 62.—The euglena, a type of animal which is much like a plant in its method of obtaining food. Note the long lash with which it swims, the large nucleus near the center of the body, and the “eye spot” near the head. With this, so called, eye the euglena discovers a place where the light is of the proper brightness for its chlorophyll to do its best work.

Some forms of euglena are not known to take in any solid food at all but live like a plant by photosynthesis. Others have no chlorophyll and live like animals by digesting food.

**Classification.**—Animals may be divided into two groups according to their method of obtaining food,—those that are *attached* and those that are *free* to move about. Those that are attached,—such as sponges, corals, barnacles, oysters, some worms, and the sea lily are all *aquatic* (Lat. *aqua* = water) and have their food brought to them by water currents. Their food consists of small plants and animals which float in the water. There is much more of this kind of food in the water than most people think there is. These animals are all simple in structure and, with some doubtful exceptions, belong to the *invertebrates* (animals without a backbone).

The animals which are free to go in search of food are more highly organized. Their senses are usually well developed. They may

swim in the water, burrow in the ground, walk, crawl, jump, or run over the earth, or fly in the air. Their food is of two kinds,—animal and vegetable. Those that eat plants are said to be *herbivorous*



FIG. 63.—The vase sponge, an example of an animal which is attached. Its food is brought to it by the movement of the water in which it lives.

(her-bīf'er-ŭs) (Lat. *herba* = plant + *vorare* = to devour). Those that eat other animals are said to be *carnivorous* (Lat. *carnis* = flesh + *vorare*). Some eat both kinds of food, they are said to be *omnivorous* (ōm-nīv'ō-rŭs) (Lat. *omnis* = all + *vorare*). Make a list of

animals and assign them to one of these three classes. Discuss doubtful cases in class.

**Adaptation.**—Each animal is remarkably adapted to obtain its particular kind of food. The teeth of horses and cows are adapted for cutting off grass and chewing it thoroughly. Cattle chew their food the second time. This is called “chewing the cud”. Of what advantage is this? Rabbits are preyed upon by foxes and other carnivorous creatures. The wonderful ability of the rabbit to hide and run is equaled by the cunning and speed of the fox which



FIG. 64.—Diagram of the compartments of the stomach of a cud-chewing animal to show the adaptations which go with the habit of chewing the cud. The food passes into the *paunch* (P) where it is stored, then into the *reticulum* (R) where the cud is formed, one at a time, then it passes up the esophagus again to be chewed. When it is swallowed the second time, it passes into the stomach at the left to be digested.

catches it. Make a list of the animals which are eaten by the fox. What are their various methods of escape? Make another list of the animals which prey upon the rabbit. Compare their methods of capturing it. Compare and discuss these lists in class.

**The foods** that are taken into the bodies of animals are reorganized and built into the animal's body by growth or repair processes, stored for future use usually in the form of fat, or are oxidized for the release energy. Animals are more active than plants and oxidize much of their food to produce heat. Because warm blooded animals are able to keep warm in cold weather, they are able to remain active in seasons of the year when cold blooded animals are at rest. Birds and furred animals are not only more active in cold weather but are very active at all seasons. This activity requires

much energy which they obtain by oxidizing more food. Of all animals, birds are the most active. Watch a wild pigeon, or a swallow, while in flight and think what a great amount of energy is being released. This explains why birds eat such large quantities of food.

**The Food Cycle.**—When carbohydrate foods are oxidized in the bodies of animals they are changed into carbon dioxide and water; thus, the animal reduces food to the elements from which it was

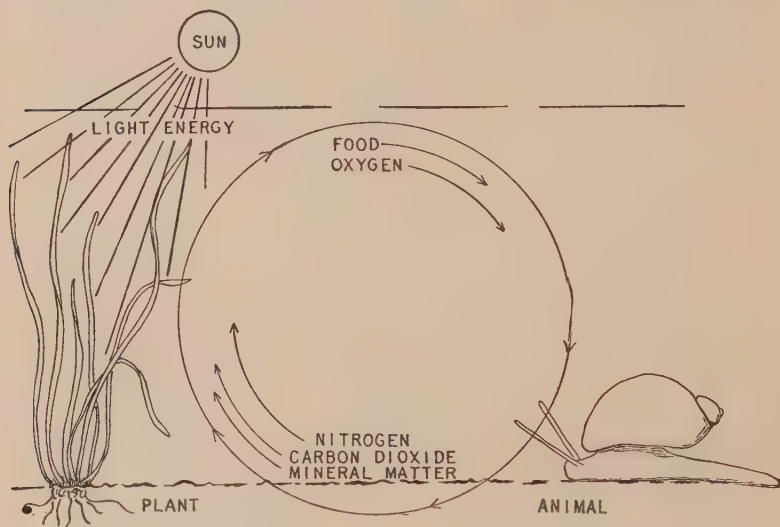


FIG. 65.—Diagram of the food cycle in an aquarium.

made by the plant. *Plants are constantly building up food matter out of simple substances and animals are constantly breaking it down into simple substances again.* These two processes are about equal on the earth and constitute what is known as the *food cycle*.

**The balanced aquarium** illustrates this principle. If water animals, such as goldfish, pollywogs, snails and protozoans are placed in a jar of water with water plants, such as algæ, duck weed and ditch moss, and the heat and light conditions are favorable, they will live together indefinitely. The animals furnish the plants with elementary food substances, and the plants are eaten by the animals.

Photosynthesis of plants is balanced by respiration of animals. The protoplasm which plants build up is broken down by animals and thrown off in simple combinations to be used again by the plants. A permanent pond illustrates this principle of the food cycle in nature very well. If you make a balanced aquarium, do not put in too many animals, for they may eat up all of the available plant material, and starve. Remember also that they may be starving with much green material apparently available, for the reason that they do not eat that kind of plant.

### OUTLINE-SUMMARY

The food of green plants, fungi, and animals compared.

Euglena as a transition type of life between the plants and animals.

Classification of animals on the basis of their food.

Special adaptations of animals to their food supply.

The food cycle and the balanced aquarium.

**Review Questions.**—How do plants and animals differ in their ways of getting food? Which are more like animals in this respect, the fungi or the green plants? How does euglena get its food? Into what three classes may animals be divided according to the food which they eat? Mention some special adaptations of animals for getting food. Why do warm blooded animals eat more than cold blooded? In the food cycle what do animals get from plants? Of what benefit are animals to plants? How may we make a balanced aquarium? What precautions should we observe?

### SUGGESTED STUDENT ACTIVITIES

**Field Trip.**—If a pond is near the school an excursion should be made to it at this time. Remove a quantity of the vegetation to the laboratory, and there make a study of the animals found on it. Make a balanced aquarium and keep it the rest of the year. Use *Life of Inland Waters* by Needham and Lloyd, Comstock Pub. Co., for identification of the forms found.

**Boy's Project.**—Can someone secure skulls of a carnivorous animal and an herbivorous animal and demonstrate the differences in the teeth to the class?

**Report.**—Appoint someone to secure illustrations and prepare a topic on *Insectivorous Plants*. The sundew, Venus' fly-trap, or a pitcher plant will serve.



**Suggested Project.**—Collect some euglena and place them in pure water in a moderate amount of light. How long do they live? What do they live on?

### References

Linville and Kelly, *General Zoology*, Ginn & Co.  
Hegner, *Practical Zoology*, Macmillan Co.  
Galloway and Welch, *Zoology*, P. Blakiston's Son & Co.  
Emmett, *Food, Health, and Growth*, MacMillan Co.

### PROBLEM 8. WHAT IS FOOD AND HOW DO ANIMALS USE IT?

**General Questions.**—Into what five classes may foods be divided? In what parts of a plant may foods be stored? What are carbohydrates? Do animals have carbohydrates in their bodies? How do plants and animals use fats and oils? Can animals make proteins if they do not eat any? What is the chemical nature of proteins? What kind of matter is alive? How do living things use mineral foods? How do they use water? What kinds of food should we eat? Which foods are the most valuable? How do we determine the caloric value of a food? Is alcohol a food? Are stimulants foods?

Foods may be stored in any part of the plant. When they are stored in sufficient quantity, and in a form which we like, the plant may be used as food for man. The following domestic plants contain food stored in the root, stem, leaf, fruit, or seed. Arrange them in a table showing where the food is stored in each case. Turnip, cabbage, beet, celery, wheat, kohl-rabi, oats, rhubarb, watermelon, radish, strawberry, cocoanut, banana, lettuce, onion, potato, sweet potato, carrot, corn, walnut, tomato, apple. After correction, place the table on the blackboard.

We all know that there is much difference in the taste and appearance of different foods. We wish to know what classes of foods there are and how the different foods compare in chemical composition and value. We will discuss five classes of foods,—carbohydrates, fats and oils, proteins, minerals, and water.

**CARBOHYDRATES.**—We have seen how plants make carbohydrates out of water and carbon dioxide using the energy of sunlight to build up carbon, hydrogen, and oxygen into a molecule of sugar or starch.





FIG. 66.—Plants which are used as food. A, the flower of cauliflower. B, stem of kohlrabi. C, the root and leaf of the beet. D, the fruit of the tomato.

We have also seen how carbohydrates are used in making other foods, such as fats and proteins; how they are built into woody and bark tissues; and how they are oxidized for the release of energy, or stored for future use. They are usually stored in the form of starch or glucose. Maple sap, sugar cane, and sugar beets contain large quantities of the sugar we use on the table. It is called *saccharose* and has the following chemical formula  $C_{12}H_{22}O_{11}$ . This means that there are twelve carbon atoms, twenty-two hydrogen atoms, and eleven oxygen atoms in a molecule of common sugar. The simplest formula for starch is  $C_6H_{10}O_5$ . This indicates that it contains less than half as many atoms.

In animals carbohydrates are found in the system in the form of *glucose* or *glycogen*. Glycogen is a substance similar to starch but soluble in water and found only in the bodies of animals. It is sometimes called animal starch. Animals do not store carbohydrates except temporarily. They use them for building other foods and in oxidation for the release of energy. A sugar similar to cane sugar, called *lactose*, is found in considerable quantity in milk and is often called milk sugar.

FATS AND OILS are formed by both plants and animals, from carbohydrates, and probably from proteins also. In plants they are stored largely in seeds but may occur in any part of the plant. Corn oil, cotton seed oil, linseed oil, olive oil, and castor oil are familiar plant oils. Butter, tallow whale oil, cod liver oil, and lard are animal fats. We will discuss the chemical composition of fats in the study on digestion.

In animals, food is usually stored in the form of fat. When so stored it may serve to retain the heat of the body. This is because fat is a poor conductor of heat. The body of the whale is protected from the arctic cold by thick layers of fat.

PROTEINS are built up in plants, as has been explained, from carbohydrates and mineral salts. *Animals can not form proteins in this way.* They must get them by eating plants or other animals. They reorganize them and make them more or less complex, but can not originate them. Proteins are very complex substances. In plants they occur in the green tissues, seeds, and all growing parts. In animals, proteins are used for building blood, muscles, tendons,

and nervous tissue. The white of an egg is an example of nearly pure protein.

### What is protoplasm?

Carbohydrates, fats, and mineral matter are not looked upon as being alive; nor is all protein material alive. The white of an egg and the casein of milk, for instance, are not alive; but *all living matter is composed of protein*. It always has water in it, and the other foods are usually present, but they can not be said to be alive unless they are chemically linked with the molecule of living protein substance.



FIG. 87.—The skeleton of a coral. This is an example of an extensive use of mineral foods.

Thus, the essential food substance which is found in living things, and which makes up the greater part of the living thing, is protein. The living material of plants and animals is called *protoplasm* and is composed of protein and water, with but few exceptions.

MINERAL FOODS, as has been pointed out, are more available to plants than to animals. Some plants use silica for building skeletons, but most rigid tissue in plants is carbohydrate material. Animals commonly build their skeletons of lime and phosphorous

compounds. Corals, clams, snails, and crayfish use much lime in building their skeletons (Fig. 67). The vertebrate animals have an internal skeleton composed largely of lime carbonate and lime phosphate.

WATER is the most universal of all foods. It is present in all food and living tissue. It is the medium of transportation in the fibrovascular tissue of plants and the blood system of animals. When the temperature gets so low that water freezes plants die or go

|                       | WATER | PROTEIN | STARCH | SUGAR | FAT  | SALTS |
|-----------------------|-------|---------|--------|-------|------|-------|
| Bread . . . . .       | 37    | 8       | 47     | 3     | 1    | 2     |
| Wheat flour . . . . . | 15    | 11      | 66     | 4.2   | 2    | 1.7   |
| Oatmeal . . . . .     | 15    | 12.6    | 53     | 5.4   | 5.6  | 3     |
| Rice . . . . .        | 13    | 6       | 79     | 0.4   | 0.7  | 0.5   |
| Peas . . . . .        | 15    | 23      | 55     | 2     | 2    | 2     |
| Potatoes . . . . .    | 75    | 2       | 18     | 3     | 0.2  | 0.7   |
| Milk . . . . .        | 86    | 4       | —      | 5     | 4    | 0.8   |
| Cheese . . . . .      | 37    | 33      | —      | —     | 24   | 5     |
| Lean beef . . . . .   | 72    | 19      | —      | —     | 3    | 1     |
| Fat beef . . . . .    | 51    | 14      | —      | —     | 29   | 1     |
| Mutton . . . . .      | 72    | 13      | —      | —     | 5    | 1     |
| Veal . . . . .        | 63    | 16      | —      | —     | 16   | 1     |
| White fish . . . . .  | 78    | 13      | —      | —     | 3    | 1     |
| Salmon . . . . .      | 77    | 16      | —      | —     | 5.5  | 1.5   |
| Egg . . . . .         | 74    | 14      | —      | —     | 10.5 | 1.5   |
| Butter . . . . .      | 15    | —       | —      | —     | 83   | 3     |

FIG. 68.—The above table is taken from *The Human Mechanism*, by Hough and Sedgwick. A well balanced meal should contain some foods of the types illustrated by both those at the top and bottom of the table.

into a state of rest, and animals become inactive, die, migrate, or have some means of keeping warm. If the earth should become cold and all the water on it freeze, life would be impossible.

**Relative Value of Foods.**—A common method of estimating the value of a food to the body is to measure the quantity of heat a unit weight of it will give off when it is burned. This method determines the amount of energy it releases when oxidized. It does not determine its value as a tissue builder.

**Calorimetry.**—A small quantity of the food is burned in a vessel called a *calorimeter*. The change in temperature is noted, and from

this the quantity of heat is determined. *Quantity* of heat is very different from *temperature*. Temperature measures the *degree of heat* but quantity is the actual *amount of heat* energy possessed by the body. A cup full of water and a kettle full may be at the same temperature, but there is more heat energy in the kettle than in the cup, because there is more hot water there.

The unit of measure of quantity of heat is the *Calorie*, generally called the large Calorie. *It is the amount of heat required to raise the temperature of one kilogram of water from zero to one degree Centigrade.\**

All foods have been tested in this way and their values recorded in tables. One gram of fat gives about 9.3 Calories; one gram of glucose, sugar, or protein about 4 Calories. Carbohydrates and proteins are of about the same value, and are less than one half as valuable as fat. In estimating foods in this way the digestibility of the food is not considered. This is a serious defect. For instance, a gram of glucose and a gram of sawdust have about the same caloric value, but sawdust is a very poor food because we can not digest it. It is, however, a good food for those animals which can digest it. Termites and many kinds of wood borers thrive on it. In spite of this handicap, the caloric method is of great importance in estimating the value of foods.

### **What should we eat?**

In selecting our food, we should consider our likes and dislikes. We have a natural desire for foods which are needed by us, but we can not depend upon this entirely. We should be sure to eat foods which agree with us. They should not cause any distress after meals. Some people can eat almost anything, and others have very delicate stomachs. We should eat a good variety of foods of all classes, and should not eat too much of any one kind. It is not wise to eat so much sugar in the form of candy that we are not hungry when meal time comes.

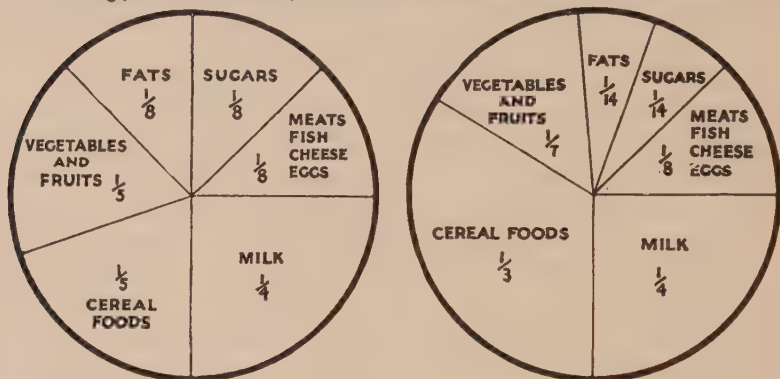
A table of the common foods showing of what they are composed is given herewith. Those at the top contain much carbohydrate material, and those at the bottom contain much fat. You will note that we seldom fail to eat a good distribution of these foods in a meal.

**Vitamins** (vī'tā-mīns) have been talked about so much during the last few years that nearly every one knows about them. Unfor-

\*The large Calorie equals 1000 small calories.



Chart reprinted from an article—"Wise Buying of Food"—by Dr. Mary S. Rose, Teachers College, Columbia University, New York City. *Modern Priscilla*, April, 1923



## A WELL-BALANCED DIET

FIG. 69.—This chart shows what kinds of food—in their relative importance—should be eaten by young people in order to furnish a well balanced ration, furnishing all kinds of growing material, and also giving variety to avoid monotony of diet.

The diagram on the left gives an ideal diet where expense is no consideration. The one on the right gives a good nutritious diet at a much lower cost.

| Food            | Calorific value | Vitamin content |
|-----------------|-----------------|-----------------|
| Cereals.....    | good            | high            |
| Eggs.....       | good            | high            |
| Fruits.....     | low             | very high       |
| Meats.....      | good            | low             |
| Milk.....       | low             | high            |
| Nuts.....       | good            | high            |
| Butter.....     | very high       | high            |
| Sugar.....      | good            | none            |
| Vegetables..... | low             | very high       |

FIG. 70.—Table to show the relative value of the kinds of food as expressed in calories and vitamins.



unately, much that has been said is exaggeration. Very few of us are in danger of suffering for the lack of them. Their chemical nature is not very well known, but in some ways they resemble proteins. Their absence in our food, or in the food of animals causes such diseases as *pellagra*, *beriberi*, and *scurvy*. Vitamins do not seem to be present in large quantities in meats and meat products, but are found in milk, butter, and cod-liver oil. Fruits, nuts, grains, and vegetables contain large quantities of them. If we eat freely of these foods and milk products, we need have no fear of a lack of vitamins in our diet.

**Is Alcohol a Food?**—No, it is not. Its calorific value is high, and it is oxidized in the body in some way, since it does not appear in quantity in the excretions after being taken into the body; but it disorganizes the system, deadens nervous activity, interferes with normal circulation, digestion, assimilation, secretion, and excretion. This makes it a poison, and a poison can not be a food. Beers and wines, minus their alcohol, contain some food matter, but most of the food of the grain or fruit is destroyed in fermentation.

**Tea and Coffee are Stimulants.**—They quicken the nervous activity for a time. Stimulants are not foods, but the milk and sugar taken with these drinks are foods. Tobacco, opium, cocaine, and chloral are examples of *narcotics*. They blunt the senses when taken in small quantities, while in large quantity they produce sleep or death. *Three drops of pure nicotine will kill a man*. These substances are *habit formers*, i.e., they so disorganize the nervous system that their presence is necessary to steady the nerves so that the individual may go about his daily tasks.

### OUTLINE-SUMMARY

Place of storage of food in plants: roots, stem, leaf, leaf stem, flower, seed, fruit.

The five classes of foods: carbohydrates, fats and oils, proteins, minerals, and water.

Calorimetry is a method of determining the value of foods, but it is not a complete measure of value.

We should eat a well balanced variety of foods.

Vitamins, alcohol, tea and coffee.

**Review Questions.**—Name a list of vegetables and state in what part of the plant the food is stored in each case. Name some of the common forms of carbohydrates. Where may they be stored? Do animals store carbohydrate? What do they store? How do animals form their proteins as compared with plants? What do we know about the chemistry of proteins? What is protoplasm? Does it contain fat or carbohydrate? What use is made of mineral foods? What is a calorie? What should be known about the value of foods besides their caloric value? How may we select a balanced ration? What foods contain much vitamin material? What foods contain small quantities? Why is alcohol not a food? Are tea and coffee foods?

### LABORATORY FOOD TESTS

**Starch** may be tested for by boiling the food, cooling, and adding iodine solution. A blue color, disappearing when the solution is heated and reappearing when the solution is cooled indicates starch.

**Glucose** may be detected by boiling the material in Fehling's solution. An orange color indicates glucose.

**Carbohydrates** usually turn black when they are covered with strong sulphuric acid.

**Oils or fats** may be tested for by digesting with ether and evaporating. The oils and fats will be dissolved out by the ether and left after evaporating their solvent. If they are abundant they may leave a clear spot on thin paper when the food is applied to it.

**Proteins** turn yellow in the presence of strong nitric acid. This color is intensified if ammonium hydroxide is added.

**Free salts** may be detected by digesting the food with water and then filtering and evaporating the water. The salts will be left as crystals.

**Water** may be detected even in very small quantities by placing the food in a test tube and holding it over a flame so that the upper part of the tube is not heated. The water will collect as drops on the inside of the tube.

The above tests may be assigned to committees and in this manner brought before the class. If laboratory facilities are adequate, each student may make the tests.

**Suggested Girl's Project.**—Can the girls of the class arrange an exhibit of 100 calorie portions of food in combinations to make meals of balanced rations? Government bulletins can be had which are helpful in this work.

## References

- Hough and Sedgwick, *The Human Mechanism*, Ginn & Co.  
*Food Values and Body Needs, Good Proportions in the Diet*, and other Bulletins of the U. S. Dept. of Agriculture.  
*Food Selection and Meal Planning Charts*, Govt. Printing Office, Washington, D. C.  
*List of Bulletins on Foods and Cooking*, Govt. Printing Office, Washington, D. C.

### PROBLEM 9. WHAT ARE POISONS, AND HOW DO THEY ACT ON THE HUMAN SYSTEM?

**General Questions.**—What is the nature of alkaloids? What poisons are found in tea, coffee, chocolate, and tobacco? What effect do they have on the system? What are the opium poisons? Is quinine a medicine? What are anesthetics? How do the metal poisons act? Are headache powders dangerous? How does alcohol damage the body?

Unfortunately, foods are not the only substances which are taken into the body. There are times when we need medicines, and when we do need them, they should be taken promptly; but there are many substances which man frequently takes which do him great harm. It is highly important that we should know about these substances. Some of them are habit formers and are taken innocently by people to kill a pain, or relieve distress. We should all know of the dangers which threaten those who use these poisons. There are times when some of them should be used, but those who continue their use should do so with a full knowledge of what the consequences may be.

ALKALOIDS are substances which are formed in plant tissues. They resemble alkalies in that they form salts with acids,—hence the name. They substitute themselves for important parts of the living protoplasm, and thus destroy it. The actions of these substances are, however, very diverse.

**Caffeine** is found in tea and coffee. It has a stimulating effect on parts of the brain. In large and concentrated quantities it is dangerous, and in small quantities is a habit former. *All alkaloids are habit formers.* Their continued use so injures the nervous system that it can not carry on its normal functions unless the drug is present. This sets up a craving, and makes it difficult for one who has become addicted to their use to get along without them.

**Theobromine** is found in chocolate and cocoa. It does little harm in the small quantities in which it exists in these foods as ordinarily used.

**Nicotine** is found in tobacco. It is a violent poison when taken even in small quantities. As has been stated before, three drops of pure nicotine is sufficient to kill a normal man. The ill effects of the use of tobacco, especially by boys, is too well known to require proof. "Human experience shows that the unwise use of tobacco may unfavorably affect digestion, cause serious disorders of the heart, and

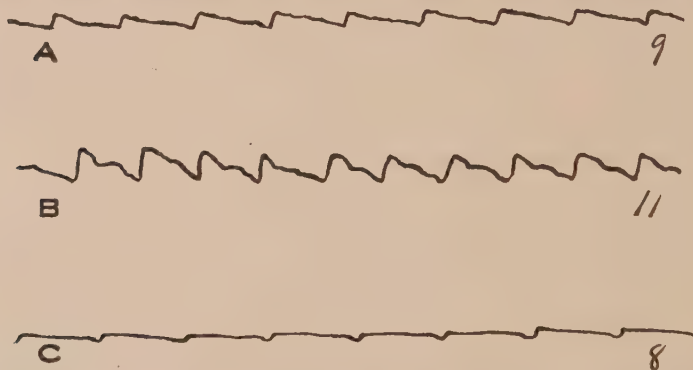


FIG. 71.—The effect of tobacco on the heart beat. A is a graph made by a normal heart. B is by a heart after the subject had smoked a cigarette. Note that the beat is faster, and stronger, and less steady. C is the graph made by a person who has lost vitality by excessive smoking. The pulse is weak and slow. The ratio of the rapidity of the beats in these cases is 9:11:8.

impair the work of the nervous system. Those training for athletic events are usually forbidden the use of tobacco because it 'takes the wind',—*i.e.*, makes impossible the most efficient training of the heart. (Fig. 71.) Many employers have found that youths who smoke cigarettes are less reliable in their work; and this is only one instance of the effect upon the nervous system already referred to, the same result being observed in a diminished steadiness of the hand, often amounting to actual tremor.

"Especially to be condemned is its use by those who have not attained their full growth. During youth nothing should be allowed to interfere with the best development of the heart and nervous sys-

tem, and the use of tobacco endangers the proper development of both of these most important parts of the human mechanism. It can hardly be doubted that many a young man has failed to make the most of life because the habit contracted in his youth has struck in this way at the foundations upon which he had subsequently to build." (Hough and Sedgwick, *The Human Mechanism*.)

**Codein, morphine, and laudanum** are made from opium which is extracted from the opium poppy. These alkaloids deaden the nerves and are, therefore, used to relieve pain. *They do not remove the cause of the pain but merely relieve the suffering of the patient.* Because of this, their use often becomes a habit which is very difficult to break. The physical, mental, and normal life of the victim is greatly impaired. When without the drug the user becomes disturbed mentally and suffers all the horrors of the insane until relieved by more of the drug. Opium victims are not wholly responsible for their acts and can not be trusted.

**Quinine** is made from the bark of the cinchona tree. It is a valuable medicine, because its presence in the blood destroys the germs of malaria. It should not be used as a drug. *Cocaine* is obtained from the leaves of coca and is used to deaden pain. *Strychnine* is obtained from the seeds of *Strychnos nuxvomica*, a tree which grows in the East Indies. It is a violent heart stimulator and a deadly poison. Besides these there are many other less known alkaloids.

**ANESTHETICS** produce sleep. **Ether** and **chloroform** are examples. They are of inestimable value in modern surgery. They cause unconsciousness, but their action on nervous tissue is not fully known. They are fat solvents and it has been suggested that they may dissolve out fat from the protein substances in nervous tissue. This has not been proven, however.

**MINERAL POISONS.**—If a soluble salt of silver, mercury, or lead is placed in the white of an egg, coagulation occurs; and the mass becomes white and opaque. The heavy metals are capable of combining chemically, from solutions of their salts, with the living protein molecule. When bichloride of mercury is swallowed, the white of an egg is given as an antidote. Why?

Workmen in lead and mercury industries are often poisoned by these metals. Recent researches have shown that the young of



animals which have been fed lead acetate in small quantity show an appreciable decrease in size and vitality. A large proportion of the young are born dead. These results hold, even when only the male receives the poison. Phosphorus affects the workmen in match factories, causing the bones to decay and the teeth to fall out. Children born of parents so affected often die in infancy, and those that live are handicapped by decreased vitality. Matches can be made by using red phosphorus or phosphorus sesquisulphide, neither of which is poisonous. The manufacture of yellow phosphorus matches is now prevented by a prohibitive tax.

HEADACHE POWDERS usually contain some chemical,—such as *acetanilid* which acts as a heart depressor. “It has long been known that acetanilid, antipyrin, and phenacetin are habit-forming drugs, particularly acetanilid. The habit is usually acquired through the use of the remedy without the supervision of the physician for the relief of minor aches and pains, especially headache. Troubles of this kind are peculiarly likely to return again and again, and the remedy has but a temporary effect; hence the dose must be repeated, and in time the patient may become dependent upon the drug. Furthermore, the ache or pain for which the medicine was first taken is often worse than ever after the effects of the remedy have passed away, because of the weakened condition of the system which may result from the use of these agents, and hence there is additional call for the remedy. Thus a habit may be established—more drug, impaired bodily health, lessened resistance, more pain, more drug.” (Kebler, Morgan, and Rupp, *U. S. Department of Agriculture, Bulletin* 377.)

ALCOHOL.—If the white of an egg is placed in a test tube and a strong solution of alcohol is placed on it, it will coagulate. (This result is not obtained with a weak solution.) Alcohol kills protoplasm by coagulating it,—*i.e.*, it draws the water out and at the same time hardens it. Its action is both physical and chemical. If strong alcohol is taken into the system in considerable quantity death results.

“The evil effects of alcohol are so continually demonstrated upon man that there is no need for experimental investigations to establish this fact. Pathological examination of the tissues in the



case of confirmed drunkards has demonstrated the existence of definite lesions in many of the organs,—stomach, liver, heart, nervous system,—and have shown that under these conditions it acts as a tissue poison.

“Regarding its stimulating action the general experience of mankind attributes a result of this kind to its use in small quantities but the experimental evidence is of an uncertain nature. Some observers have claimed that the reaction time is diminished after the use of alcohol, but most of the recent investigation goes to show that in the work of skilled labor, in which the neuromuscular machinery is involved, alcohol even in small quantities decreases the efficiency. It has been suggested, therefore, that as regards the higher nerve centers, it acts from the beginning as a narcotic or paralyzant to the inhibitory centers. By thus removing inhibitory control there is an apparent increase in activity which is not due to a direct stimulating effect.” (Howell, *Physiology*.)

The removal of inhibitory control destroys judgment. For this reason the partially intoxicated man talks freely and often wittily but more often foolishly. In cases of excessive drinking the victim becomes more irrational, stumbles, falls, and passes into a drunken stupor. If this is repeated often a complete breakdown of the nervous system sets in, and even when sober the man appears to be unbalanced. He finally becomes a raving maniac and thinks he sees all sorts of snakes and horrible creatures. This is the climax of continued intoxication and is called *delirium tremens*. It often ends in death.

Many people believe that alcohol gives warmth to the body. Professor Howell says, “It is known that even in small doses it causes a dilation of the skin vessels, giving a feeling of warmth and leading to increased loss of heat”. This fact has long been known by arctic explorers who universally condemn the use of alcohol on their journeys.

“The capital argument against alcohol, that which must eventually condemn its use, is this, that it takes away all the reserve control, the power of mastership, and therefore offends against the splendid pride in himself or herself, which is fundamental in every man or woman worth anything.” (Walt Whitman.)

## OUTLINE-SUMMARY

Alkaloids: caffeine, theobromine, nicotine, codein, morphine, laudanum, quinine.

Anesthetics: ether, chloroform.

Mineral poisons: silver, mercury, lead, phosphorus.

Headache powders are dangerous.

Alcohol, effect on protoplasm, effect on organs of the body, stimulating action, effect on judgment, effect on blood pressure, effect on self respect.

**Review Questions.**—Why is it important to know about the dangers of drugs? What is the effect of drinking tea and coffee? Is chocolate dangerous? How does nicotine effect the system? What is the effect of opium on the human body? Of what value is quinine? For what do we use ether and chloroform? How do the mineral poisons effect protoplasm? Is phosphorus dangerous to the children of parents which are poisoned by it? How? How did the government stop the manufacture of poisonous matches? Why should we avoid headache powders? What is the effect of alcohol on protoplasm? What organs of the body may be damaged by alcohol? Is alcohol a stimulant? Does it keep one warm in winter? Why is a drunkard's nose red? Does a drunkard have pride in himself, or confidence in his ability when he is sober?

## LABORATORY WORK

**Teacher's Experiment.**—Place some white of egg in five test tubes. Treat one with a soluble salt of mercury, another with a soluble salt of lead, another with a soluble salt of silver, heat one, and treat the other with strong alcohol. Prepare another set and treat them with various strengths of alcohol.

The student should understand that the protoplasm was destroyed in the above tests. What is a poison? Why is egg-white an antidote for the poisons mentioned above?

## References

- Hough and Sedgwick, *The Human Mechanism*, Ginn & Co.  
Howell, *Textbook of Physiology*, W. B. Saunders Co.  
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## PROBLEM 10. HOW ARE FOODS DIGESTED AND ABSORBED?

**General Questions.**—What is digestion? Why is digestion necessary? Do plants digest food? What are the parts of the digestive tube? What are the uses of the mouth? The esophagus? The stomach? The intestine? What happens to food in the stomach? What are the digestive juices? How do they act? How do foods get out of the intestine and into the blood?

How many of the above questions can you answer? It will be profitable for us to know the answer to all of them, if we can. The

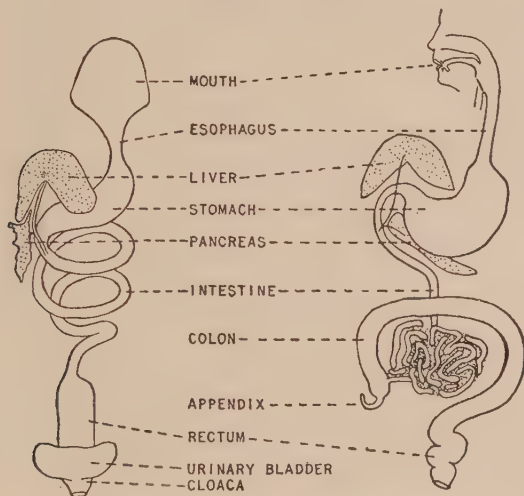


FIG. 72.—The above diagrams are intended to show the difference between the food tubes of the frog and man. Note the shape of the stomach, and the comparative length of the intestine.

first thing to do in the study of digestion is to get a general idea of the digestive apparatus. It is quite similar in all of the vertebrated (backboned) animals. Make a careful study of the figure which shows the digestive tube of the frog and man in a comparative way (Fig. 72). Learn the names and positions of all of the parts.

We will begin our study where it is the simplest—in plants.

**Digestion in Plants.**—*Digestion is the preparation of food for absorption.* The food of plants exists in the soil or air in a soluble

condition and digestion is not necessary. However, the root hairs of plants secrete acids which help to render the solid food elements

soluble. This is digestion in spite of the fact that it occurs outside of the body of the plant.

You may have observed that when yeasts, moulds, and bacteria are acting on foods that the foods are watery in consistency. This condition is produced by the bacteria and other fungi as a digestive process by which the foods are reduced to fluids in which condition they can be absorbed by the fungus plants which are absorbing them by osmosis.

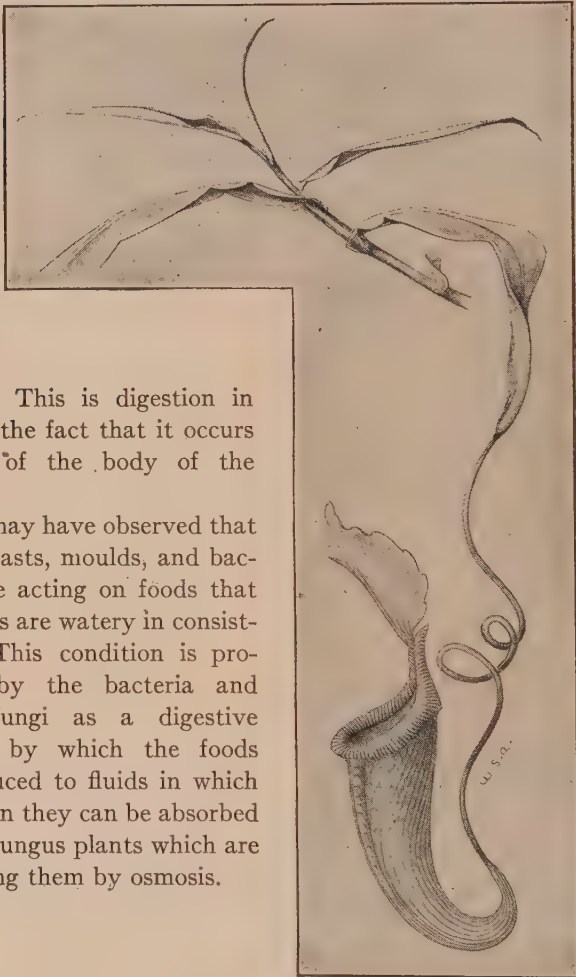


FIG. 73.—A tropical pitcher plant. Insects are caught in the "pitcher" at the end of the leaf. (*Jenkins.*)

Some plants; such as the Venus fly-trap, pitcher plants (Fig. 73), and sundew catch insects and spiders in their leaves and digest them. These plants feed like animals and are notorious exceptions in plant life. They usually grow in poor soil and have acquired the habit of using animal food to compensate for the lack of plant food.

**Digestion in Animals.**—In the vertebrate animals the digestive apparatus is known as the *alimentary canal* (Lat. *alimentum* = food).

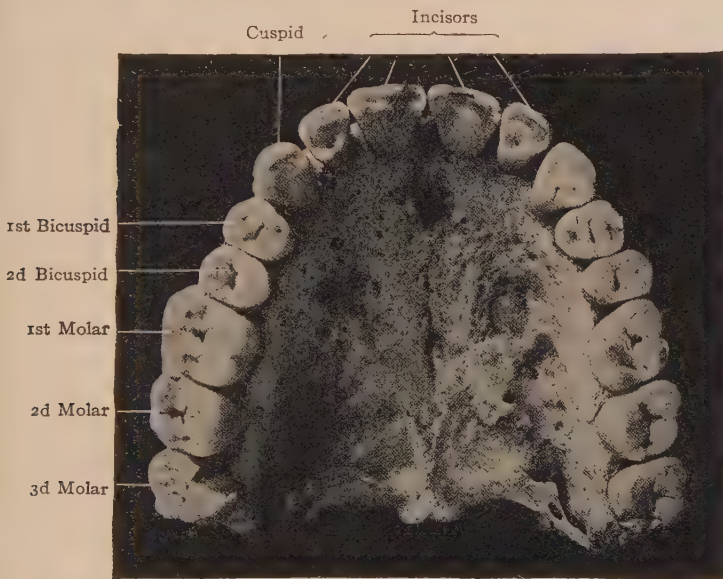


FIG. 74.—Teeth of the upper jaw to show their names and arrangement. The front teeth cut food, and the back teeth chew it. How are they adapted to do this work? (*Broomell and Fischelis.*)

It is composed of the mouth, esophagus, stomach, and intestine. The liver and pancreas are organs which are derived from the intestine in development and aid in digestion. Compare the alimentary canal of the frog with that of man (Fig. 72).

**The mouth** varies greatly in different animals. Birds and turtles have no teeth. Many reptiles, fish, and frogs use their teeth for holding their prey but do not chew their food. Many insects chew their food but have no true teeth. In the matter of chewing they have advanced beyond any of the vertebrates except the mammals



(animals with hair over the body and which feed the young on milk). The jaws and teeth of mammals are so constructed that they can grind their food very fine. This is a great aid to digestion and gives this group a great advantage over all others except the insects (Fig. 74).

Three pairs of *salivary glands* secrete a juice called *saliva* which is passed into the mouth. It serves to soften the food so that it may be more easily swallowed and begins the digestion of carbohydrates. The digestive substances are called *enzymes* (ěn'zîms: Gr. *enzymos* = fermented). Their nature is not very well understood, but they are capable of causing chemical changes to take place in other substances without being changed themselves. Because of this a small amount of an enzyme may do a large amount of work if given time. The enzyme in saliva is called *ptyalin*. It does not act in a strongly acid solution. It changes the starch molecule, by a complex process, to several kinds of carbohydrates and finally to *maltose* ( $C_{12}H_{22}O_{11}$ ), a sugar similar to cane sugar. Maltose is ultimately changed to glucose ( $C_6H_{12}O_6$ ), in the intestine where it is absorbed.

**In the stomach** the food is churned by the muscular action of the stomach walls and is mixed with *gastric juice* (Gr. *gaster* = a stomach). This juice is secreted by glands in the walls of the stomach and is composed mainly of *hydrochloric acid* (HCl) and two enzymes, *rennin* and *pepsin*.

**The hydrochloric acid** neutralizes the slight alkalinity (alkalies are the opposites of acids) of the saliva and renders the contents of the stomach distinctly acid. Pepsin will not act unless it is in an acid solution; hence, the hydrochloric acid is said to *activate* the pepsin.

**Pepsin** begins the digestion of proteins. They are first reduced to simple proteins and finally to amino acids if digestion continues long enough, but they pass into the intestine before they are reduced this far, and are probably not all reduced to amino acids even there, but some may be absorbed in the more complex form. Hydrochloric acid is also able to digest protein of itself.

**Rennin** changes casein, one of the proteins of milk, into an insoluble curd. It may be used to curdle milk. This curd is then acted upon by the pepsin. Another enzyme similar to rennin is found in the pancreatic juice.



**Intestinal Digestion.**—The food remains in the stomach one or two hours and then passes, a small amount at a time, through the *pyloric valve* (*Gr. pylorus* = gate) into the intestine. Here it is mixed with the *pancreatic juice* from the pancreas, the *bile* from the liver, and the *intestinal juice* from the walls of the intestine.

**The bile** contains no enzymes. It is alkaline and neutralizes the hydrochloric acid which was secreted in the stomach. The pancreatic juice does not act in an acid medium, and the bile is said to *activate* the pancreatic juice somewhat as the hydrochloric acid does the pepsin. The bile also helps in the digestion of the fats as we shall see.

**The pancreatic juice** from the pancreas contains three principal enzymes—*trypsin*, *amyllopsin*, and *lipase* or *steapsin*. Trypsin completes the digestion of the proteins, and amyllopsin completes the digestion of the carbohydrates. We have discussed the chemical composition of the proteins and carbohydrates in the previous study and it need not be repeated here. It is enough to say that by adding water to the molecule these two classes of foods are reduced to simpler substances and rendered soluble so that they can pass through the walls of the intestine by osmosis.

**Digestion of Fats.**—We have put off the study of the chemical nature of fats until now, because their composition can be best understood in connection with the study of their digestion. They are composed of two parts—an **acid** and **glycerine**. When these chemicals come together to form fat, some water is thrown out; consequently when they are digested water is absorbed. There are many of these plant and animal acids which combine with glycerine to make fats, therefore there are many different fats. There are also many combinations of the different fats. In fact, it is not possible to find an oil or a fat in nature which is of only one kind of fat. Tallow and mutton fat are said to be **heavy fats**, and oils are said to be **light**.

It is well known that fats and oils will not dissolve in water. They must be changed to soluble materials before they can pass through the wall of the intestine. This is why they must be digested, for digestion is the process of changing them so that they will osmose through the wall of the intestine and into the lymph (body fluids which are poured into the blood).

The **lipase** of the pancreatic juice, in its enzymic action on fats, causes the alkalies in the intestine to unite with the fats. This breaks them up into the two materials of which they were composed in the first place—namely, glycerine and acids. The glycerine remains as it is, and is soluble in water. It needs no further digestion. The acids combine with the alkali to make *soaps* which are soluble in water. This process is very much like the process of forming soaps commercially, with the exception that, in industry, the enzyme, lipase, is not used to produce the chemical action. The products are the same.

If **bile** is not present in the intestine, from forty to sixty per cent of the fats which are eaten are not absorbed, but pass through the body undigested, and are wasted. Therefore it is thought that bile aids in keeping the digested fats in solution until they are absorbed.

The **intestinal juice** has no important enzymes. It is strongly alkaline and serves to keep the contents of the intestine alkaline. The formation of soaps from fat and the action of bacteria both make the contents of the intestine acid if constant secretion of intestinal juice is not kept up. If the contents of the intestine should become acid, soaps would not remain in solution, or fats and oils would not be changed at all but would pass out undigested the same as if no bile had been produced. The work of the intestinal juice seems to be to keep the contents of the intestine alkaline, thus continuing the work which was begun by the bile.

The table below sums up the facts of digestion. Learn it so that you can reproduce it from memory on the blackboard.

#### TABLE OF THE DIGESTIVE JUICES

##### MOUTH: Saliva

- |             |                           |
|-------------|---------------------------|
| 1. ptyalin— | digests carbohydrates.    |
| 2. mucin—   | lubricates the esophagus. |

##### STOMACH: Gastric juice

- |                       |                                       |
|-----------------------|---------------------------------------|
| 1. hydrochloric acid— | digests protein and activates pepsin. |
| 2. pepsin—            | digests protein.                      |
| 3. rennin—            | curdles milk.                         |

**INTESTINE: Bile, pancreatic, and intestinal juices**

1. bile— activates pancreatic juice.
2. trypsin— digests protein.
3. amyllopsin— digests carbohydrates.
4. lipase— digests fats.
5. intestinal juice— maintains alkalinity in intestine.

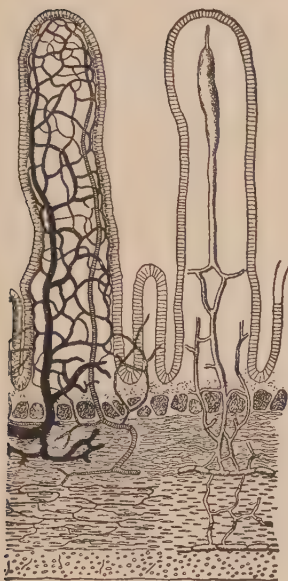


FIG. 75.

FIG. 75.—Diagram of two intestinal villi. In the one to the left the blood vessels are shown, and in the one to the right the lacteal and its connections are seen in the center of the villus. In passing through the walls of the villus the carbohydrate and protein food is first taken out by the blood; and the fat, after passing the network of blood vessels is absorbed by the lacteal. (*Hough and Sedgwick, The Human Mechanism.*)

FIG. 76.—Diagram to show how the digested food gets from the intestine to the circulatory system. Note that the fats enter the blood stream directly, and that the carbohydrate and protein foods must pass through the capillaries of the liver before they reach the heart.

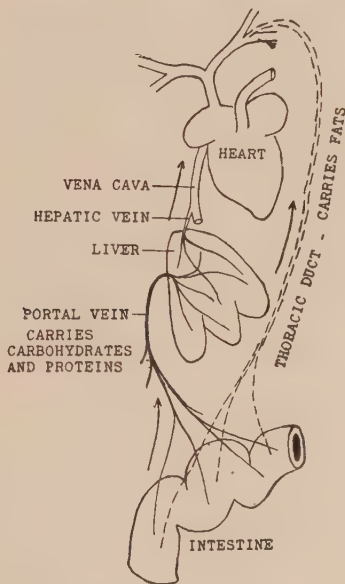


FIG. 76.

**Absorption** is confined almost exclusively to the intestine and takes place by osmosis of the dissolved food through the walls of finger-like processes which project into the interior of the intestine. They are called *villi* (Sing. *villus*) which in Latin means “shaggy

hair". (Fig. 75.) Each villus is lined with a network, of fine blood vessels and has in its center a duct called a *lacteal*. The digested carbohydrates and proteins are absorbed by the villi where they enter the blood and are carried to the liver through the *portal vein*. (Fig. 76.)

**The carbohydrates** pass into the blood in the form of glucose and are changed into glycogen in the liver and stored temporarily. Only a certain amount of glucose is allowed in the blood under normal conditions except in the portal vein where it may exist in considerable quantity after a carbohydrate meal. Glycogen is changed back into glucose as it is needed, and, thus, a constant quantity is maintained in the blood. This quantity is regulated by the liver. Glucose in the blood is the same as that of the laboratory. Pure glucose may be injected into the blood and be used as food. Very few other substances can be used in this way.

**Amino acids and simple proteins** are not found in the blood. It is thought that the proteins are reformed in the villi, but not much is known about this as yet. The protein foods are oxidized in the liver and reorganized to be carried by the blood to all parts of the body where they are used mainly for growth and repair.

**The fats** do not enter the blood stream directly but pass beyond the network of blood vessels in the villus and enter the lacteals. These lacteals unite to form larger tubes and finally form a trunk called the *thoracic duct* which is a part of the lymphatic system and enters the blood system through one of the large veins near the heart. Fats may be absorbed as soaps, glycerine, and fatty acids; but neither of these substances appears in the lymph or blood in appreciable quantity. Therefore, fats, like proteins, are probably reformed in the villi. Small globules of fat are normally present in the blood and lymph.

#### OUTLINE-SUMMARY

Digestion is of little consequence in plants because their foods are in solution in the soil.

Digestion begins in the mouth, is continued in the stomach, and completed in the intestine. The action which takes place in each of these organs is summed up in the table of digestive juices.

Fats are composed of an organic acid and glycerine combined chemically. When they are digested they are broken down into these elements and the acid unites with alkalies to form soaps.

In absorption foods are taken up by the villi which line the inner wall of the intestine. The fats enter the lymphatic system. The carbohydrates and proteins enter the blood system and pass to the liver, from where they enter the general circulation.

**Review Questions.**—How do plants usually obtain their food? How do some plants obtain animal food? Compare the digestive tubes of the frog and man. Name the teeth which we have in our mouth. How many are there of each kind? What happens to food in our mouths? What happens to it in the stomach? Of what value is bile in digestion? Where is fat digested? What is the chemical relationship of fat and soap? What is the chief value of the intestinal juice? How do foods get through the intestinal wall? How do fats get to the blood? Compare with proteins and carbohydrates. When carbohydrates are digested, what do they become? Proteins? Fats?

### SUGGESTED LABORATORY DEMONSTRATIONS

**Mouth Digestion.**—Saliva may be placed on boiled starch for about an hour. Test the mixture for glucose. You may also test some of the original starch for glucose. If the test of starch is negative and the test of the starch-saliva mixture is positive, what did the saliva do to the starch? (See p. 108.)

**Stomach Digestion.**—**Pepsin** may be had from drug stores or from dealers in biological supplies. Prepare some boiled egg. Mince the white very fine. Place some pepsin solution in four test tubes. To the first add nothing, to the second add a drop of dilute hydrochloric acid, to the third add several drops of dilute hydrochloric acid, and to the fourth add two drops of an alkali (NaOH). Place some minced egg in each test tube and stand away in a warm place for one or two days. In which of the tubes has digestion taken place? Why did it not take place in all of the tubes? In which did it go on the most rapidly? This experiment may be performed by each of four or five students and the entire class may view the results if time and space are limited. Write it up completely in the notebooks and state which tube was the most representative of the actual conditions which exist in the stomach.

**Intestinal Digestion.**—**Pancreatin** may be used in a similar manner to illustrate intestinal digestion. The only place where fats are digested is in the intestine. If you wish to digest fats, use corn oil, cottonseed oil, or olive oil. The pancreatin



must be fresh and of the best quality or results will be disappointing. It may be made alkaline by adding a little sodium carbonate.

**An emulsion** may be made to show to the class by mixing a light vegetable oil with a dilute alkali and shaking. Does the fat remain emulsified? For how long? **Soap** will form from this emulsion if it is left to stand or is warmed. An understanding of the chemistry of soap-making is helpful in understanding the digestion of fats.

**Absorption.**—Our problem here is **why are foods digested?** Use two diffusion shells such as are sold by the dealers in biological supplies. Suspend each in a vessel of water. Place some **starch** which has been mixed with cold water in one and some **glucose** or **honey** which has been diluted slightly in the other. After some time test the water in the first vessel for starch. Test the water in the second vessel for glucose. Did the starch osmose? Did the glucose? Which digestive juices change starch into glucose? Why is this necessary?

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### PROBLEM 11. HOW ARE RESPIRATION AND CIRCULATION RELATED TO FOOD AND OXYGEN?

**General Questions.**—How do plants and animals release the necessary energies for their life work? How is food carried to the muscles? How are waste products carried out of the body? How does oxygen get into the blood? How is oxygen carried in the blood? Why do we breathe? What are the uses of the blood? How does the blood system of man compare with that of other animals? How does our method of breathing compare with the breathing of other animals?

We now come to the last problem on the study of food. We have learned how food is obtained and built up by living things. We have also considered some of the uses to which it is put. We have seen how it is used to build up stems, leaves, and other parts of plants; and we have seen how animals use food to build up their bodies. We have also seen how they store food for future use; but we have not given much consideration to the energies of living things. In this study we are to consider how plants and animals use foods to

release the energies which are necessary to keep them alive and active.

### What is the source of the energies of life?

The simplest means of obtaining energy from food is by oxidizing glycogen or glucose. We have learned that these substances are carbohydrates, and that they contain carbon, hydrogen, and oxygen. Wood is another good example of a carbohydrate material. If we wish for an example of how energy may be released from such material, we may think of a wood fire. We all know that the wood is burned, or *oxidized*. The carbon in the wood takes on oxygen and becomes carbon dioxide gas. The hydrogen in the wood takes on oxygen also and becomes water. It is by a somewhat similar process that food materials are oxidized in our bodies. They are changed into carbon dioxide, water, and other chemical products. The process differs from the burning of wood chiefly in that it is slower, and that no light is given off. Of course, the reason why light does not appear is that not enough heat is generated.

**Oxidation of fats and carbohydrates** yields water and carbon dioxide. The energy released by oxidation is used in muscular, glandular, and nervous activities, and in other ways. The more extensive these activities are the larger is the amount of oxygen required. Birds consume large quantities of food and oxygen, and their body temperature is higher than that of mammals. Turtles and frogs can live a year without food and remain under water all the time, if kept cold.

**The blood of animals** is of value in the processes of releasing energy. Food is carried by it to all parts of the body, because wherever there is work to be done, there must be food from which to release the energy. Blood is composed of a fluid called the *plasma* in which red and white corpuscles float freely (Fig. 77).

**The red corpuscles** are by far the more numerous and they give the blood its color. Their chief constituent, other than water, is

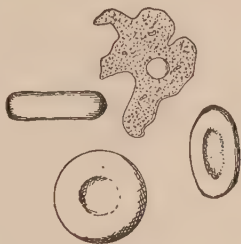


FIG. 77.—Red and white blood corpuscles. Note that the red corpuscles are shaped somewhat like a disc wheel and tire. The white ones may assume almost any shape.

a complex protein containing iron, potassium, and phosphorous, called *hæmoglobin*. It is capable of taking up oxygen where it is plentiful and releasing it where it is scarce. When it contains much oxygen it is bright red in color.

**The white blood corpuscles** are *ameboid* (like an ameba). They change their shape as does an ameba and feed in a similar manner. Bacteria are destroyed in large numbers when they are present. They assemble in places where infection occurs, and, thus, help the body to fight off disease. At times so many bacteria are taken in by the white corpuscles that they die. This may produce pus as in boils, and infected cuts. Another interesting characteristic of the white corpuscles is that they are able to get out of the blood vessels and travel to almost any place in the body.

**Coagulation.**—When the blood flows out of a wound it sets, or *coagulates*. This is caused by the formation of fine, white fibers of a complex protein material called *fibrin*. If they are removed as fast as they form, no coagulation takes place. Coagulation prevents bleeding to death when a small artery is opened. If the blood flows from a deep wound in the arm or leg in pulses, an artery has been opened, and a tourniquet should be applied. Apply a bandage of this kind to the arm of one of the students in the class as a demonstration. It may be made with a handkerchief and a pencil.

**Breathing** is also associated with the release of energy in plants and animals. If there were no oxygen, there would be no oxidation. As it is necessary to carry food to all parts of the body, oxygen must also be carried to every part where energy is to be released. Animals obtain oxygen by a process called *respiration*. The simplest process of respiration known is that of the *ameba*, an animal which is composed of but a single cell. It lives in water and absorbs oxygen from solution in the water by *osmosis*. We have studied osmosis in connection with the study of roots of plants. There are no special breathing organs. Oxygen enough to satisfy the wants of ameba may be had because the animal is composed of but one cell, and all of its parts are near the source of supply; but in animals of many cells oxygen must be carried from special breathing organs to the places where it is needed.

**Circulation and oxidation in plants** is not so extensive as in animals. Circulation takes place through fibrovascular tissue, as has been explained, and is concerned chiefly with the distribution of food, but some oxygen is carried in solution. In many water plants special tubes occur for carrying oxygen to the roots which, being under water do not have good access to air. These air passages serve also to float the stems and leaves (Fig. 78).

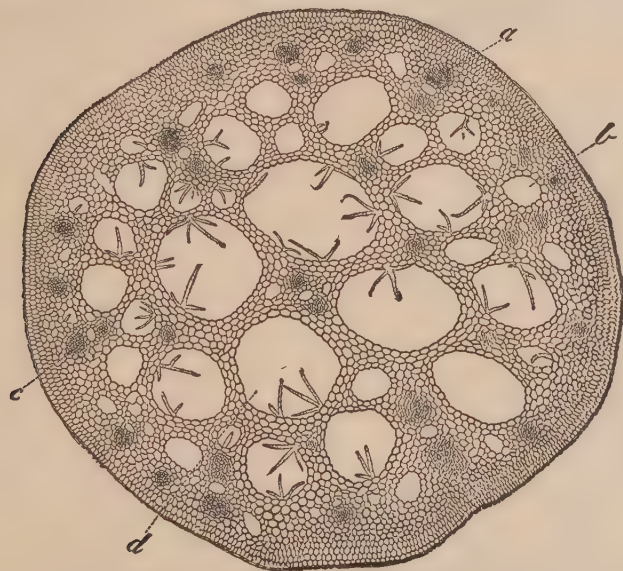


FIG. 78.—Cross section of the leaf stem of the white water lily to show the large air passages. They help to furnish the parts under water with air and also to float the leaves; *a* and *c* are the sap ducts; *b* and *d* are the air tubes. (*Green.*)

**The earthworm** has a good circulatory system (Fig. 79) but no special respiratory organs. Oxygen is absorbed by the moist skin and is carried by the red blood to all parts of the body. The blood also carries food from the intestine to all parts of the body.

**In insects** the respiratory and circulatory systems are separate. Oxygen is carried to all parts of the body by a system of tubes called *tracheæ* (Sing. *trachea*). The blood system is poorly developed.

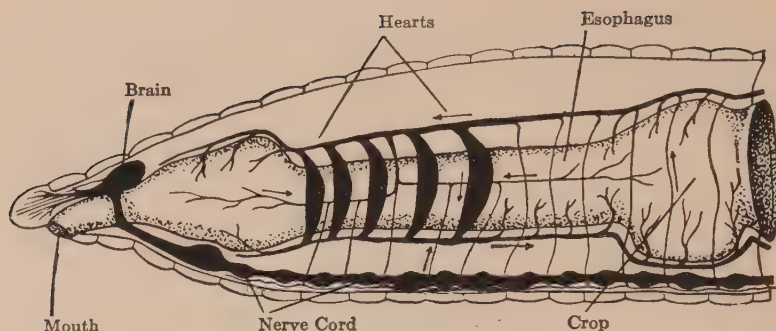


FIG. 79a.—Diagram of the earthworm to show its nervous system, circulatory system, and digestive system in their relation to each other. Only the head end is shown. Arrows indicate the direction of the flow of the blood. There are ten hearts in five pairs which pump the blood from the dorsal vessel to the ventral.

Small blood vessels which are not shown collect oxygen which has been absorbed by the skin and carry it to all parts of the body. In a similar manner carbon dioxide is carried to the skin to be given off.

Digested food is taken up from the walls of the intestine by small vessels and is sent through the hearts to all parts of the body where it is used. Other small vessels carry blood to the digestive system. These are shown in the figure.

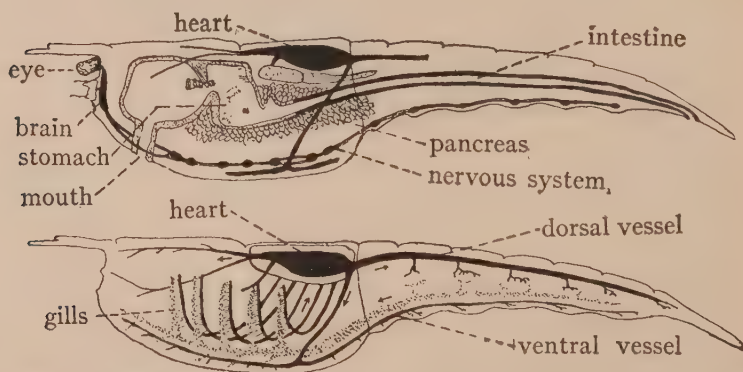


FIG. 79b.—The digestive system, nervous system, and blood system of the crayfish to show the relation of each to the other. Note that there is but one heart which pumps blood forward, backward, and to the ventral vessel. It returns to the heart from the gills through spaces called sinuses. They are shown in black lines in the lower figure. (Redrawn from Hamaker.)



Spiders, scorpions, and the horseshoe crab breathe with *lung-books* which are structures containing parallel plates arranged like the leaves of a book.

Crayfish and crabs breathe with structures called gills, but they are much different from the gills of fish. The blood system of these forms is poorly developed but carries both food and oxygen.

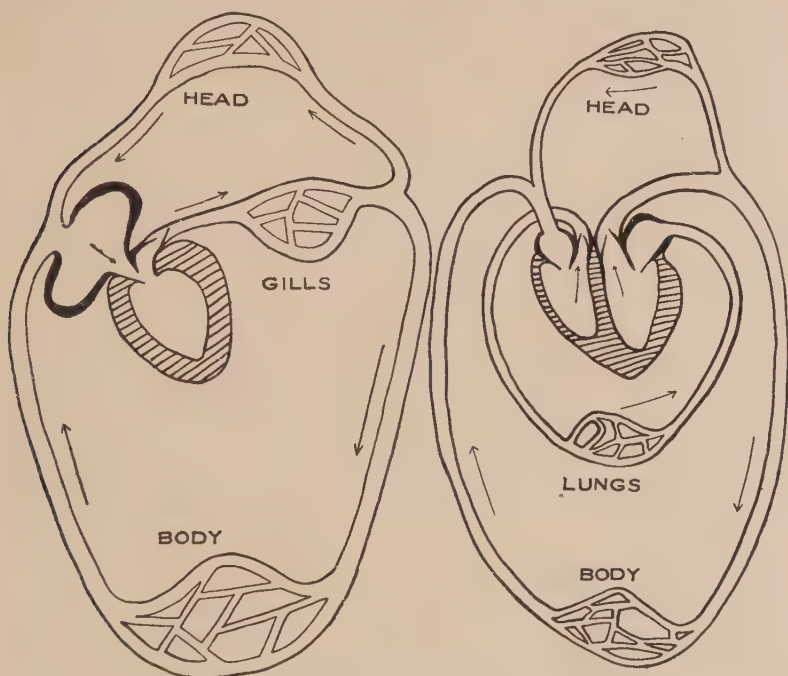


FIG. 80.—Two diagrams to show the differences between the circulation of a fish and a mammal. Note that the fish has gills and the mammal lungs. The blood passes through the fish heart once, and through the mammal heart twice. The fish heart has one ventricle, the mammal heart has two.

Fish have a two chambered heart and breathe with gills (Fig. 80). Their circulation differs from that of other vertebrates in that it passes through the heart but once in making a complete circuit of the body.

Frogs and toads have a three chambered heart and breathe with lungs and through their moist skin. They begin life as tadpoles and

have a two chambered heart and gills like that of a fish. In the fish the blood passes from the heart to the gills, to the body and back to the heart, and to the gills again, and so on. In the frog the blood passes from the heart to the lungs; then back to the heart, and then to the body; then back to the heart, and then to the lungs, and so on. The ventricle of the heart in both forms is single, and oxygenated and deoxygenated blood mingle there to a certain extent in the frog, but the fish heart receives only deoxygenated blood.

**Birds and mammals** have the ventricle divided completely by a partition. This makes a four chambered heart. The flow of the blood is similar to that of the frog, but there is no mingling of pure and impure blood in the ventricle of the heart. Birds and mammals are warm blooded and live more active lives than the lower forms. This is why they use so much oxygen and eat such large amounts of food.

### SUMMARY

We have seen in this problem that living things obtain energy by oxidation, and that food and oxygen are circulated through their bodies. Respiration and circulation of various types of life were compared briefly. *It is the fundamental purpose of respiration to furnish the oxygen supply for oxidation and to help eliminate from the body the products of combustion. It is the fundamental purpose of circulation to carry food and oxygen to places where they are needed and to carry the waste products to the excretory organs.*

**Review Questions.**—How do plants and animals use food? Why do they oxidize food? What chemical products result from the oxidation of food? Why do birds use much oxygen? Compare red and white corpuscles. What are the uses of each? How does blood clot? How does the ameba respire? Why do plants oxidize little food? How does the earthworm respire? How do insects respire? How do spiders and crayfish respire? Compare the hearts of fish, frogs, and mammals.

### SUGGESTED EXPERIMENTAL WORK

Perform some of the experiments suggested in Atwood's *Problems, Projects, and Experiments in Biology*, P. Blakiston's Son & Co., pp. 39-41. Also Eddy's *Experimental Physiology and Anatomy*, American Book Co., pp. 43-47 and 72-85.

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#### UNIT IV. HOW LIVING THINGS GROW AND REPRODUCE

The growth of plants is associated in our minds with spring and summer. The renewal of life after the winter rest is one of the great wonders of nature. The seeds of plants and the eggs of animals are most carefully prepared and, in many cases, very elaborately provided for so that the next generation may be assured of existence. If seeds and eggs fail year after year, the species of plant or animal can not continue to exist and must become extinct. The numbers of extinct forms of life are far greater than those which have survived. It would be difficult to say which of the life activities is the most important, but surely there is no more important process in life than providing for the next generation. It seems that the creature grows to maturity with the purpose of reproduction of the race as the most important end of life. In the fall of the year we see the millions of dead plants and think that they grew all through a long summer only to produce seed and die. These seed must grow again the next season or the plant will be no more. It is for just this reason—the failure to live to reproduce—that all extinct forms of life have perished. This unit is to be devoted to the closely allied subjects of growth and reproduction.

## STUDY 1. THE CELL, ITS GROWTH AND REPRODUCTION

**General Questions.**—What are the units out of which living things are made? Who first described a cell? What are the characteristics of a cell of *spirogyra*? What are the parts of a typical cell? How do cells multiply?

As a house may be made of bricks so the bodies of plants and animals are composed of units. In 1665 an Englishman, Hooke, wrote a book in which he described the microscopic appearance of cork. This was shortly after the invention of the compound microscope. He saw that there were rows of chambers in the cork. These he called “cells” because they resembled the cells of monks, which



FIG. 81.—A cell of *spirogyra* seen in cross section and side view. C, chloroplasts; CW, cell wall; N, nucleus; P, protoplasm; PY, pyrenoid; S, cell sap.

were arranged in rows along hallways. It was many years after this that biologists came to think of the protoplasm which had occupied the cells of Hooke as the cell instead of the space within the walls, but the name “cell” has continued in use.

A cell of *spirogyra* is shown in figure 81. If you look at a cell of this alga through the microscope, you will see that it is one of a chain of similar cells all of which are joined end to end. It has a *cell wall* which is cylindrical in shape. Within the cell wall there are one or more spiral bands of green protoplasm called *chloroplasts* (klō'rō-plāsts). Along these bands are denser areas called *pyrenoids*. In the center of the cell the *nucleus* may be seen as an irregular body with streamers running out from it to all parts of the cell. If the



cell is stained with iodine solution, the nucleus may be seen more easily. The fluid within the cell is called *cell sap*. We may think of this cell as a typical plant cell.

**The nucleus** is the most important part of the cell; without it the cell can not remain active and ultimately dies. It is usually centrally located, and unless obscured by coloring matter, it may be seen under the microscope. A nucleus is normally bounded by a

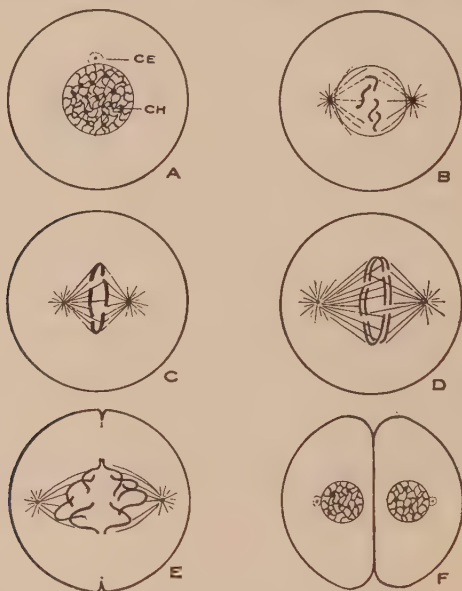


FIG. 82.—A diagram of cell division. The stages of the process are described in the text.

*nuclear wall*, on the outer edge of which a body, called the *centrosome*, appears in the cells of many of the animals, but is not seen in the cells of plants. The protoplasm within the nucleus is traversed by a network of fibers called *linin*. A small, round body, called the *nucleolus*, is usually present. Its significance is unknown.

The most important structures within the nucleus are the chromosomes (Gr. *chroma* = color + *soma* = body), so called because they are easily stained in microscopic preparations. They are of various

shapes and sizes, and at some stages in the life history of the cell seem to disappear, but their identity is never lost. They are always found in constant number and form, in any species of plant or animal.

### How do the cells divide?

In the higher plants and animals, cell division takes place by a process known as *mitosis* (Gr. *mitos* = thread). The process is similar for both plants and animals except that plant cells do not have a centrosome. We will describe a general type which should be modified to fit special cases.

1. In figure 82, A shows the resting animal cell with its nucleus containing chromatin and linin (CH), and the centrosome (CE). The centrosome divides and the halves migrate around the nucleus, or move apart and the nucleus is drawn up between them. Around each of the halves of the centrosome, rays appear, which cause them to look like stars (B). Hence they are called *asters* (Gr. *aster* = star). *The chromatin is organized into a definite number of bodies*—four in this case—which are the chromosomes. They migrate to the central plane of the nucleus and arrange themselves there in the form of a circle (C), and are suspended by ray-like processes from the asters. The entire figure resembles a *spindle* and is so called. The spindle occurs in both plant and animal cells. It is often compounded in plants.

2. In the second stage, *each chromosome splits longitudinally into two equal halves* which soon move apart (D). It is important to note that the splitting is lengthwise, for this leaves each half like the other.

3. In the third stage *the chromosomes move toward the asters*; probably under the influence of the rays of the spindle, and finally group themselves near the poles of the spindle (E).

4. In the last phase *the process is completed* and two new nuclei are formed. They are similar to the one from which they were derived except that they may be smaller in size (F). By the time the process is complete the cell wall has usually constricted the cell into two equal halves, but in some cases the cell does not divide equally.

We shall refer now to the second figure (83) which represents conditions as they appear in plants. For review and comparison note that within the nucleus a ribbon is formed. It breaks up into sections which split lengthwise. The split portions move apart and

collect at the sides of the cell. Each group helps to form a nucleus. A cell wall divides the cell into two cells

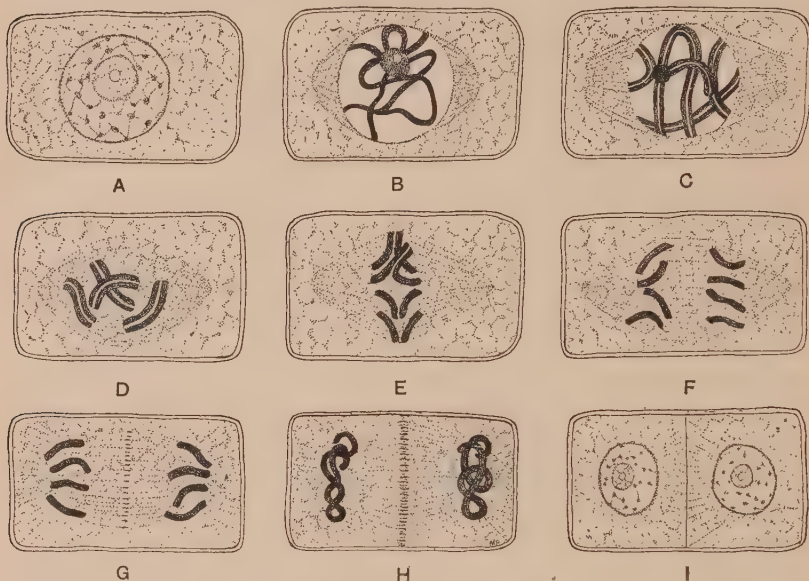


FIG. 83.—Diagram to show cell division (mitosis) in plant cells. (Gager.)

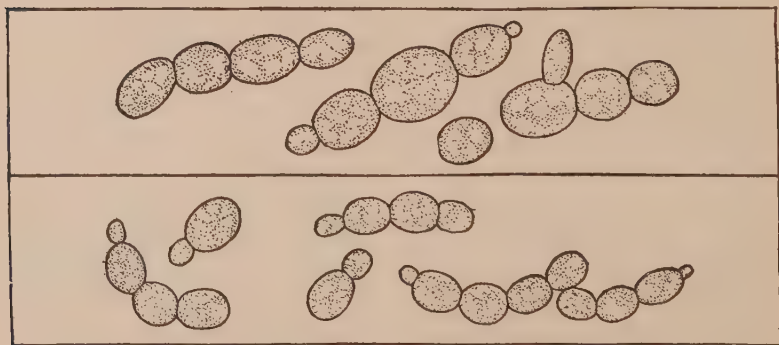


FIG. 84.—Yeast cells, to show their method of growth by budding. (Marshall.)

**Budding** is a special form of cell division which occurs in the growth of yeast cells. As is shown in figure 84, a small bud appears on the

side of the cell. It grows until it is as large as the parent cell, when it may become detached, or the cells may remain united forming chains.

**Bacteria** divide by a very simple process. When the cell has reached its full size, it divides in its middle to form two, but there are no nuclei in the cells. The material which corresponds to nuclear protoplasm seems to be distributed throughout the cell, and no chromosomes are known to form in the division of bacteria. This very simple process of cell division is called *fission* which means to split.

**Growth.**—After cells have divided they are smaller than before. At this time they absorb food and grow rapidly. The method of getting food is very simple. Whatever there is in their vicinity, which they need, may be taken in by osmosis. If the cell lives alone in water as the spirogyra plant, each cell must get its own food; but if the cells are a part of the body of a plant or animal, they may have food brought to them by the sap or blood. In either case, the food passes through the cell wall by osmosis. Each cell lives its own life so far as the use of this food is concerned. Cells like spirogyra are able to do all kinds of work to maintain their lives, but cells such as muscle cells are not able to do all kinds of work, and must have their food brought to them. The bodies of the higher plants and animals have many kinds of cells in them. Each type of cell is designed to do a special kind of work, but none of them could live alone. Thus each cell does its part in keeping the creature alive.

#### OUTLINE-SUMMARY

The unit structures of plants and animals are cells.

The parts of a typical cell as of spirogyra described.

In cell division chromosomes appear in the nucleus. They are always equal for any species and for all cells of the body, but differ for different species. In cell division they are also divided so that the number remains constant within the plant or animal.

Yeast has a special method of division called budding.

Bacteria have a very simple method of dividing called fission.

Cells get their food by osmosis from their surroundings or from other cells of the plant or animal of which they are a part. Some

cells perform all of the functions of life while others are specialized and can do only one thing.

**Review Questions.**—Describe the cell of *spirogyra*. Describe the nucleus of a cell. What are chromosomes? Describe the process of cell division and the splitting of the chromosomes from diagrams which have been copied on the blackboard. How do yeast cells increase in number? How do bacteria divide? How does a cell obtain food? How does food getting in *spirogyra* and a muscle cell differ?

### LABORATORY SUGGESTIONS

Various types of cells may be observed under the microscope. If the students are skilful in the use of the high power of the instrument, chromosomes may be seen in the root tip of the onion. Permanently mounted slides for this purpose may be had from the dealers. Yeast may be grown and its cells observed. *Paramecia* may be grown in a hay infusion and the process of cell division observed in the living animals as they swim about on the microscope slide.

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### STUDY 2. GROWTH AND REPRODUCTION OF SINGLE-CELLED ANIMALS

**General Questions.**—What are protozoans? Where do they live? How does the ameba live? How does it reproduce? What do they do when the pond in which they live dries up? How does *paramecium* live? What is conjugation? What is its purpose?

PROTOZOANS (prō-tō-zō'ans) are single-celled animals. The majority of them are free-living, but some are parasitic. They are found in both salt and fresh water, and are exceedingly abundant. We have previously mentioned some of the responses of ameba, euglena, and *paramecium*. In this study we shall use two of these types to illustrate reproduction in protozoans.



**Ameba.**—In many ways ameba is the simplest of the protozoans. It lives in the mud or on the surface of objects in ponds. It can be raised in the laboratory by placing some pond weeds in a dish of water and allowing them to decay. The amebas can usually be found on the sides of the glass jar or in the scum which forms at the top of the water.

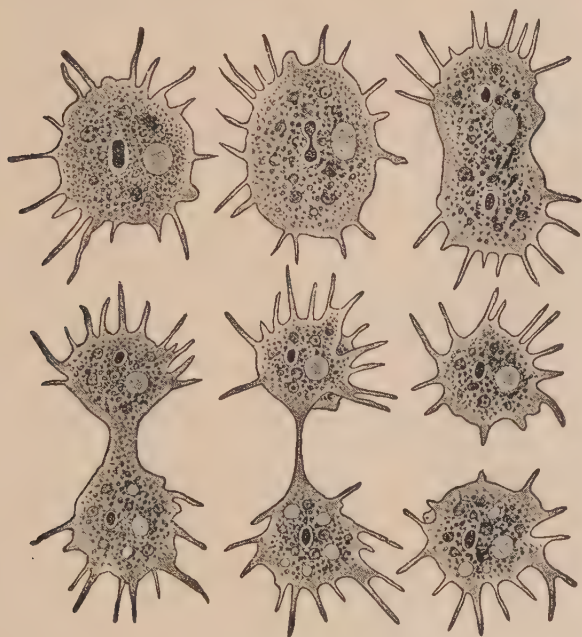


FIG. 85.—Six drawings of an ameba to show how one divides. Note how the nucleus separates and how the cells pull apart. (Doflein.)

*In feeding*, an ameba puts forth processes called *pseudopodia* (sū-dō-pōd'ī-à) (false feet) which flow around the food particle and thus take it into the body. It is surrounded with a fluid, the food parts are absorbed, and the remains cast out. Material may enter or leave the body at any place.

*Respiration* is carried on through the entire surface of the body. When the ameba grows to a certain size (about  $\frac{1}{100}$  of an inch) it is no longer able to supply its body with enough oxygen through its

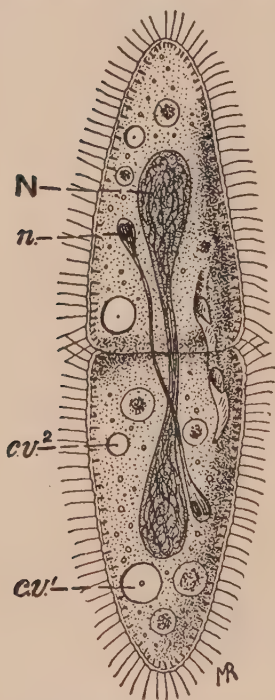
surface. This is because, as the animal grows, the volume increases as the cube of the diameter, and the surface only as the square. Thus the surface is no longer able to absorb enough oxygen to maintain the life of the ameba. The solution of this difficulty is the

division of the animal into two equal parts. Each part becomes an independent individual half the size of the parent.

**Reproduction.**—When division takes place the nucleus divides and each part migrates to an opposite side of the cell. As this is taking place a constriction occurs around the cell so that it assumes the shape of a dumb-bell for a time before finally separating (Fig. 85).

Scheel describes another method of reproduction in ameba called *sporulation*. The pseudopodia are drawn in, the animal becomes a sphere, and a heavy case is formed around it. Movement may be observed within the case for several days; then the nucleus begins to divide. It passes through several divisions, and five or six hundred nuclei are formed, each surrounded by a bit of protoplasm. Finally the case breaks open, the spores escape and grow within a few weeks to mature amebas.

FIG. 86.—Transverse division in *Paramecium*. *N*, macronucleus; *n*, micronucleus; *cv*, contractile vacuoles. (Minchin.)



and begin an active life again. This explains why it is that amebas may be found in ponds that dry up in the summer.

**Paramecium** is more highly specialized than ameba. It has a definite shape, a definitely located mouth, and the waste material always leaves the cell at a definite point. Pseudopodia are not formed, but the animal is covered with hair-like processes called

*cilia*. They are movable and are used to swim with through the water and to draw food particles to the mouth.

Paramecia reproduce by division (Figs. 86 and 87). They are not known to reproduce by any other method. There are two nuclei in paramecium,—one large one called the *macronucleus* and a small one called the *micronucleus*. The large one probably controls the activities of the cell, and the small one has a very important part to play in reproduction. In division both nuclei divide and the new nuclei move toward opposite ends of the animal, and then the cell divides transversely. Division usually takes place once or twice a day and is completed in about two hours after it starts.

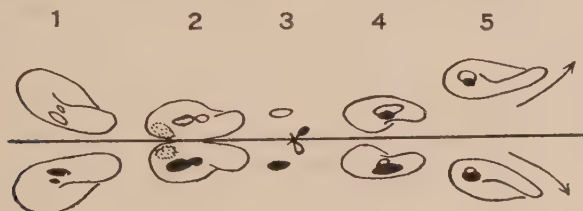


FIG. 87.—Diagram of conjugation in paramecium. In 1 the two cells come together with two nuclei each shown in black and white for comparison. In 2 the large nucleus begins to break up, and the small one divides to form two nuclei. In 3 each trades a nucleus with the other. In 4 the nucleus received fuses with the one which remained in each case. In 5 the paramecia swim apart, each with two kinds of nuclear material,—its own and also that of its mate.

**Conjugation.**—The protozoans have been said to be immortal,—*i.e.*, they never die a natural death, but continue to divide and live on forever if not killed. However, it is doubtful if division could go on forever if it were not for a process called *conjugation* which takes place after a protozoan has passed through many divisions. In conjugation two individuals come together. Their bodies fuse and each receives a portion of the nucleus of the other. Conjugation has been said to be a *rejuvenating process*,—*i.e.*, the old ameba has its youth restored. All amebas produced by the first few divisions after conjugation are looked upon as *young*; later they all become *mature*, and finally after many divisions they all become *old*. Thus an ameba is young or old throughout its entire life. The old ones conjugate, restore their youth and vigor and begin another series of divisions.

The ideas which we have just expressed about the youth and old age of protozoans are known as the *rejuvenation theory*, and are not accepted by all biologists. There are good reasons to believe that the advantages of conjugation are to be found in its value to heredity and variation. We have seen that, by trading portions of their nuclei, each has a different heredity after conjugation than before. This is assuming that heredity is controlled by the nucleus. If this theory is true, conjugation is a process which tends to keep heredity constant in a general way. Since there is a mixing of hereditary elements at each conjugation, the kinship of all protozoans of a certain species is maintained. By this same theory, small variations are more numerous, because each individual has inherited from two cells instead of one as in ordinary cell division. If the general characteristics of heredity are kept stable, and a great variation of minor characteristics is provided for, it is believed that the creature will be able to adapt itself to new situations more fortunately, will have a better chance of living, and, therefore, it is a good thing for the race. This philosophy may be a bit involved for you. It may be necessary for you to read this paragraph over again carefully.

### OUTLINE-SUMMARY

Protozoans are abundant single celled animals living in both salt and fresh water.

Ameba eats solid food with the aid of its false feet. It breathes through its surface and must divide when it gets too large. In reproduction the cell divides into two parts. Another method of reproduction is by sporulation. When a pond dries up the amebas in it form cysts which withstand the drought.

Paramecium is more highly specialized than ameba. It swims actively. It has two nuclei.

In conjugation protozoans come together and trade parts of their nuclei. This has been thought to be a rejuvenating process, but it may also be an aid in keeping the species uniform and in affording greater variation of the individual, thus aiding in adaptation to new or changing conditions.

**Review Questions.**—How does the ameba feed? How does it breathe? How does it reproduce? What does it do in time of

drought? How does paramecium swim? Why are protozoans said to be immortal? How do paramecia conjugate? What is the rejuvenation theory? How may conjugation be related to variation and heredity?

### LABORATORY SUGGESTIONS

Large numbers of paramecia may be raised in the laboratory by placing hay or dry grass in jars containing water and adding a little pond-water, or water from an aquarium. In about two weeks they may be seen as tiny white specks collecting near the surface of the water.

The protozoans may be studied alive by means of the microscope, from charts, or from models. It may be possible to secure a moving picture reel showing some of them in action.

**Problem.**—Starting with one young ameba, how many would there be after ten divisions? After twenty divisions?

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### STUDY 3. THE LIFE HISTORY OF ALGÆ

**General Questions.**—What are algæ? Where are they found? How do they get their food? How do they reproduce? How do they differ from each other?

We are all familiar with the large green plants which grow in woods and fields, but we are not so well acquainted with the slimes and floating plants of our ponds and streams. These plants must be studied with a microscope. There are hundreds of kinds of them, and they are all very beautiful, when seen through the microscope, even if they are slimy and look like scum otherwise. We are especially interested in them because they represent the simplest types of reproduction in the plant kingdom. We must understand the reproduction of the algæ first, or we will not easily understand the reproduction of the higher plants.



### How do the simplest plants grow and multiply?

ALGÆ are the simplest plants which possess chlorophyll and are capable of making starch, and thus are able to live an independent life. They are found in moist places or in water. Some of the forms which live in the ocean are rather complex in structure. Algæ may be divided into four classes as follows:

I. **Blue-green.** *Gleocapsa*.

II. **Green.** *Pleurococcus*, *Spirogyra*, *Vaucheria*.

III. **Red.** Mostly marine forms.

IV. **Brown.** Mostly marine forms.

**Gleocapsa** (Fig. 88) is a single celled alga of the first class. The cells are spherical and of a pale blue-green color. They are grouped

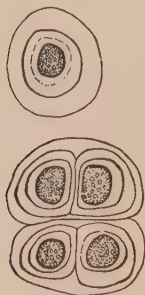


FIG. 88.—*Gleocapsa*, a single cell above and a group of four below, showing the method of multiplication.

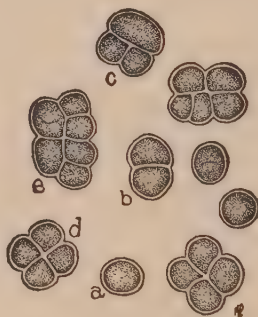


FIG. 89.—*Pleurococcus*, to illustrate its method of division. (Gager.)

in colonies and are covered with a jelly-like envelope which holds them together. The cell structure is very simple; the green matter being distributed evenly throughout the cell, and no nucleus can be seen. *Gleocapsa* lives in still water and on objects in damp places.

Reproduction takes place by a simple division of the cell into two equal halves. This process is called *fission*. Later the old gelatinous envelope breaks up, and the two cells may separate; but more often the cells remain within the old envelope; and sometimes accumulate in colonies containing eight or sixteen cells. No other

method of reproduction is known. If the water dries up, they go into a resting condition and become active again when conditions are favorable.

**Pleurococcus** (Fig. 89) belongs to the green algæ. It is the green coating found on old tree trunks, fence posts, and similar situations. It is a single cell and has no gelatinous envelope as has *gleocapsa*. The cells are composed of an outer wall surrounding a green body called a *chloroplast* which is suspended in the protoplasm of the cell and nearly fills it. It is variable in size and contains a dense portion called a *pyrenoid*. (Pyrenoids have not been discovered in the blue-green algæ.) A distinct nucleus may be seen in the center of each cell of *pleurococcus*. If the cells are soaked in strong salt water, the chloroplasts will shrink away from the nuclei, so that both may be seen.

*Reproduction* takes place by cell division very much as in *gleocapsa*. In some near relatives of *pleurococcus* which live in the water, an additional method of reproduction occurs. Several small cells may be formed within the wall of the parent cell. The old cell wall breaks and the daughter cells escape. Each is provided with two small hair-like lashes called *cilia* (singular, *cilium*). These wave in the water and enable the young cells to swim. After a time they come to rest, lose their cilia, and become like the parent cell. Special cells which are formed in this way and are capable of developing into a plant like their parent are called *spores* (Gr. *spora* = seed). If they are able to swim, they are called *zoöspores* (Gr. *zoön* = an animal). Algæ which produce swimming spores have a better means of distribution than those that reproduce by fission only. Thus we see that *pleurococcus* and its allies are more complex in both structure and methods of reproduction than the blue-green alga, *gleocapsa*.

**Spirogyra** is a green alga also, but of a more complex type than *pleurococcus*. It may be found in ponds and in slow flowing streams in great abundance in summer, either floating or entangled with weeds and grass. It often forms great masses of green slime in stagnant ponds. The cells are cylindrical and are attached together end to end, forming *filaments*. This condition is the result of the method of cell division which is always in parallel planes. The cells

divide transversely, and thus the length of the filament is increased. (See Fig. 81.)

**The chloroplasts** are spiral bands of chlorophyll extending throughout the length of the cell. The number of bands differs in different species, and there are several pyrenoids in each band. The nucleus is large and may be seen without staining.

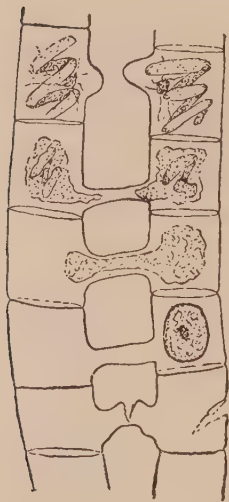


FIG. 90.—Two filaments of *spirogyra* in conjugation to show how the zygospore is formed. In the two upper cells a tube is being put across. In the next pair the contents of the one on the left is passing over to fuse with that of the right side. Below is the completed spore. The empty pair of cells show the crack in the cell wall through which a spore is supposed to have dropped out.

**Nutrition** is carried on by absorbing carbon dioxide, salts, and oxygen from the water by osmosis. The chloroplasts function the same as the green tissue of the higher plants, manufacturing starch. Each cell makes its own food, and is independent, in this respect, of the other cells of the filament.

**Conjugation.**—We have studied the process of conjugation in *paramecium* in the previous study. A somewhat similar process takes place in *spirogyra* (Fig. 90). At times tubes are put forth from the sides of cells in filaments which lie close together. The tubes from two cells unite end to end and fuse as shown in the figure. This tube forms a passage between the two cells. The contents of one cell pass through the tube and fuse with that of the other leaving one cell empty. This mass of protoplasm from both cells goes into a resting condition and produces a thick outer wall for protection. When conditions are right, it germinates; and by cell division, it produces a filament like one of the two from which it came.

In conjugation in *spirogyra* the two conjugating cells are apparently alike, and the fusion is complete and permanent. The resting spore thus formed is called a *zygospore* (Gr. *zygon* = a yoke + *spore*) (Pro. *zī'go-spōr*), and the two cells which unite are called *gametes* (Gr. = husband or wife). This method of producing a spore is said

to be *sexual* because there is a union of protoplasm from two different cells. The union of two gametes of equal size and structure is called *isogamy* (i-sog'ăm-ē) (Gr. *isos* = equal + *gamos* = marriage).

**Vaucheria** (Pro. vâ-kē'-ri-ä) is a filamentous alga which may be looked upon as having lost the dividing walls of its cells which make up the filaments, thus making the filament a continuous tube filled with chloroplasts and containing many nuclei. In sexual reproduction, processes grow out from the side of the filament. One type of structure is large and sac-like; the other is long, coiled, and tube-like (Fig. 91). The large structure contains but one large gamete

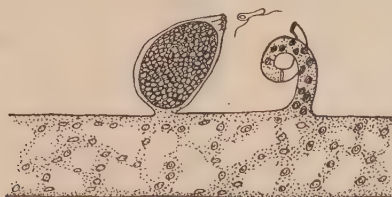


FIG. 91.—A portion of a filament of *vaucheria*, to show an oogonium containing an egg, and an antheridium which has released its sperms. The two-ciliated sperm is shown enlarged.

which is called an *egg*. The tube is called an *antheridium* and produces many small, two-ciliated gametes called *sperms*. A sperm fuses with an egg and fertilizes it. It then becomes an *oöspore* (egg spore), and may reproduce the plant.

*Fertilization* differs from *conjugation* only in that the gametes which fuse are of unequal size, and an *oöspore* differs from a *zygospor*e in the same particular.

### SUMMARY

We began this study with *gleocapsa* which does not conjugate and, therefore, has no sexual reproduction. We described *pleurococcus* and mentioned a rapid method of reproduction by spore formation. There is provision for distribution of the plants to new localities by means of swimming zoöspores. We studied conjugation in *spirogyra* where the gametes are alike (*isogamy*) and *vaucheria* where the gametes are not alike (*heterogamy*). We note here an increasing

complexity of the method of reproduction, and running parallel with it an increasing efficiency, in the provision for storage of food in the large eggs which, when they germinate, should have an advantage over the small spores of simpler algæ.

**Review Questions.**—Where do algæ live? What four classes are there? Describe gleocapsa. How does it multiply? Where does pleurococcus live? How does it multiply? Describe the appearance of spirogyra. How does it get its food? Describe the process of conjugation in spirogyra. Describe the way vaucheria develops sperms and eggs. What advantage has vaucheria over spirogyra in reproduction?

### SUGGESTED FIELD TRIP AND LABORATORY STUDY

Make collections of algæ from a pond. Pleurococcus may be collected from tree trunks. Make aquaria and keep the specimens in the laboratory. What animals do you find living among the algæ? Some of the specimens should be observed under the microscope or projected on the screen by the lantern. What forms require much light? What forms little? Do the forms which you put in the jars stay there or are they superseded by other forms? Do goldfish eat algæ?

If living material showing the various types of reproduction can not be found, preserved material can be had from dealers. Specimens showing conjugation, isogamy, and heterogamy may be permanently mounted on microscope slides.

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### STUDY 4. THE LIFE HISTORY OF MOSSES

**General Questions.**—Where may we find moss plants? Do they have true leaves and stems? Why are they always small? Are there male and female moss plants? Why are mosses said to reproduce by an alternation of generations?

Moss plants grow erect in close formation in all sorts of situations. They are found in barren fields, on the roofs of houses, in bogs, on old logs, and in the water. Although they are found in a great



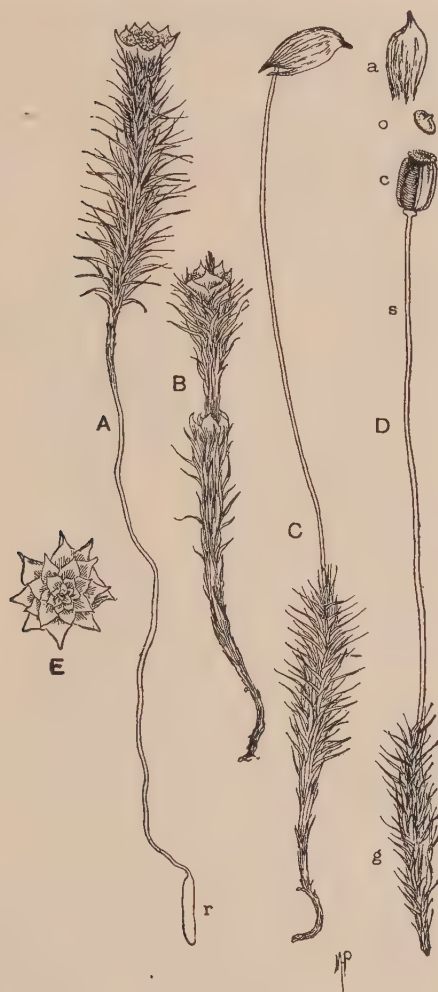


FIG. 92.—Four drawings of the hair-cap moss. The two on the left are male plants. The top of one is shown at *E*, and the plant at *B* has taken on a secondary growth. *C* and *D* are female plants with sporophytes growing out of them. The hood (*a*) and lid (*o*) have been removed from the capsule (*c*) in the figure *D*. (*Gager.*)

variety of situations, they always grow where the struggle for room is not intense. Thus, they avoid competition with the higher plants. (See Fig. 193.)

The leaves of the moss have no resemblance to the leaves of the higher plants except in external appearance. They are arranged spirally around the stem and are composed of flat cells joined together by their edges so as to form a tissue one cell layer in thickness, except along the middle of the leaf where there is a doubling of the layer. Fibrovascular tissue is not found in either the leaf or the stem of the moss plant. Its absence causes the flow of cell sap to be slow and limited. For this reason the moss plants can not lift themselves far above the source of moisture.

Moss plants are of two kinds called *male* and *female* (Fig. 92). Both plants are shown in the illustration. Male plants can be distinguished from the female plants by their flat tops. It is in these tops that sperms are produced. Each season the male plants grow a little taller "by adding another story" to their structure. The plant labeled B in the illustration is in its second season.

Female plants frequently have long bristles growing from their tops. These bristles end in cases which contain spores. The bristles are not a part of the female plants, but are a third kind of moss plant which are not only attached to the female mosses but get their nourishment from them also. They are shown in C and D.

In the previous study we have traced the development of the reproductive processes in the algæ from *fission*, through *spore formation*, to the development of *gametes* which conjugate; and finally to the development of sperms and eggs. In the present study we shall consider a more advanced type of reproduction known as *alternation of generations* in which an asexual spore producing plant gives rise to a sexual spore producing plant, which produces the asexual plant again. Thus, we have two kinds of plants and two kinds of spores in each life history.

### How do mosses reproduce their kind?

The male plants produce sperms, and the female plants eggs. The sperms are produced in many celled, club-shaped structures called *antheridia* (Gr. *antherose* = flowery) (Fig. 93). They are borne on the top of the male plants. In the presence of sufficient moisture

the antheridia swell, the tips break open, and the sperms escape. They are able to swim actively by means of their two cilia.

The eggs are developed in flask-shaped structures called *archegonia* (Gr. *arch'e* = first + *gonos* = race). They are found on the top of the female plant (Fig. 93). An egg is developed in the base of

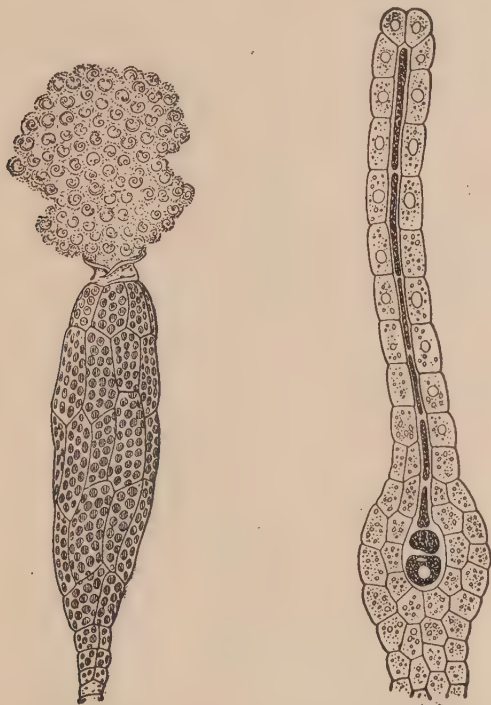


FIG. 93.—An antheridium and an archegonium. Sperms are shown issuing from the top of the antheridium. An egg is shown at the base of the archegonium. The long black cells in the neck of the archegonium will break up and form a passage for the entrance of a sperm. (*Bergen and Davis, after Sachs.*)

the archegonium, and when it ripens the neck becomes a hollow tube down which a sperm may swim to fertilize the egg. The egg is retained in the base of the archegonium after being fertilized and develops into a long, slender structure—the *sporophyte*. One end of this structure grows down into the base of the archegonium and

comes into intimate contact with the cells in the upper part of the moss plant. This part is called the *foot*. It serves to anchor the sporophyte to the moss plant, and at the same time it absorbs food. The other end of the sporophyte develops into a slender stem called a *seta* (bristle) and bears a capsule at its upper end. The remains of the old archegonium usually remain as a *calyptra* (hood) on the upper end of the capsule. Beneath the calyptra is a lid, the *operculum*, and beneath this is a ring of triangular teeth which close the opening to the inside of the capsule. (See the illustration).



FIG. 94.—Young moss plants to show how they grow from the protonema. (Gager.)

In tracing the life history we will begin with one of the asexual spores produced in the capsule at the upper end of the sporophyte. The asexual spore germinates and produces a branched filament similar to that of the algæ, but differing from the algæ filaments in that the cross walls are oblique. It is called the *protonema* (Gr. *protos* = first + *nema* = thread). It forms a felt-like mat on the surface of moist soil. Some of the cells at the ends of branches become swollen and later divide to form a several celled *bud* (Figs. 94 and 95). Its resemblance to the buds of higher plants is in its appearance only, but from it the erect stem of the moss grows.

We have seen that there are male and female plants, and that the male plants produce sperms, and the female plants produce eggs. When the egg develops into a plant, it does not become a moss plant like its parent, but grows on the female plant and produces spores in its spore case. It was with one of these spores that we started to trace the life history, and now we are back to it again. It should be easily seen now why mosses are said to have an alternation of generations. When the male and female plants produce sperms and eggs, they do not reproduce themselves but the alternate form which produces spores. Because it produces spores it is called a *sporophyte* (spor'ō-fīt). The other generation is called a *gametophyte* (gam'et-ō-fīt) because it produces gametes (sperms and eggs). Thus we see that a sporophyte generation alternates with a gametophyte generation.



FIG. 95.—A young moss plant and its protonema to show the cross walls and buds.

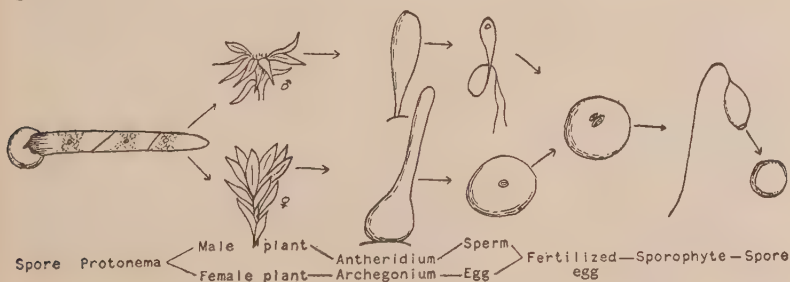


FIG. 96.—Diagram of the life history of a moss plant.

### SUMMARY

Mosses grow in many situations, but have no stems or true leaves. They can not transport sap far from the soil because they have no fibrovascular tissue.



They reproduce by an alternation of generations. The green moss produces eggs and sperms. The fertilized egg develops into a plant without chlorophyll which lives on the green moss and produces asexual spores. These spores develop into an alga-like protonema on which the moss plants grow.

**Review Questions.**—Where are mosses found? Describe a moss plant. Compare the protonema with an alga. Why are they called gametophytes? Why is the other generation called the sporophyte? Describe in writing the complete life of the moss.

### SUGGESTED STUDENT ACTIVITIES

**Field Trip.**—Make a collection of mosses. Dry and mount some of the choice specimens for the museum cases. Make a list of the situations in which you find mosses growing.

**Suggested Project.**—Will some one try to raise moss plants in the laboratory? The air of the room will be too dry for them. They must be kept under glass in a moist atmosphere.

**Laboratory Work.**—The entire life history of each of the four groups of plants may be worked out from preserved material, charts, and microscope slides; but probably all students may not care to do this work.

### References

- Densmore, *General Botany*, Ginn & Co.  
Bergen and Caldwell, *Practical Botany*, Ginn & Co.  
Bergen and Davis, *Principles of Botany*, Ginn & Co.  
Gager, *Fundamentals of Botany*, P. Blakiston's Son & Co.  
Marshall, *Mosses and Lichens*, Doudleday, Page & Co.

### STUDY 5. THE LIFE HISTORY OF FERNS

**General Questions.**—Where do ferns grow? In what way are their leaves and stems more efficient than those of mosses? Where do ferns bear their spores? Do they have an alternation of generations?

Ferns are found in many parts of the earth. They grow in dry fields, in deep woods, and in deserts; but it is in the tropics that they reach their greatest variety. The *tree ferns* of the topical forests may grow to a height of forty feet. Some kinds have abandoned the habit of growing on the ground and live on the branches of trees.



FIG. 97.

FIG. 97.—The small fern, *Polypodium*, which grows on the bark of trees. Natural size. (Hamaker.)



FIG. 98.

FIG. 98.—Adder's tongue fern showing the relationship of leaves (L) to the sporophyll (Sp). Note also the underground stem and roots (R). (Gager.)

The moist tropical air supplies them with water, and they get their mineral food from the decaying bark and dirt which accumulates about their roots. (Fig. 97.)

**The roots and stems** of our ferns do not rise above the ground. Leaves are borne on long leaf-stems and are called *fronds*. Some of them may be especially modified to bear spores and do little or no



FIG. 99.—Photograph of the magnified cross section of the underground stem of a fern. Note the ring of hard cells (stone cells) in the center of the stem. The fibrovascular bundles are both within this ring, and just outside it. The bundles grow in size as the stem grows. At first they are round, but become elongated as they increase in size. (Gager.)

photosynthetic work. These are called *sporophylls* (Gr. spora = seed + *phyllon* = leaf). (See Fig. 98.)

The great advantage that ferns have over mosses is that they possess *fibrovascular tissue*. This makes the development of roots and a stem possible, and permits the sap to flow readily from one part of the plant to another. The roots and stems of ferns are, however, not so well developed as those of the flowering plants; and

for this reason they either grow where the competition is not severe, or have developed the ability to live in the shade of forest trees.

### **How do ferns differ from mosses?**

In the moss the gametophyte or sexual phase of the life history is the most prominent. In the fern the sporophyte is the prominent phase, the gametophyte is seldom seen, and is unknown to most people. The sporophyte of the fern has overcome its dependence upon the gametophyte and developed roots, a stem, and leaves as have the flowering plants; but it still reproduces by spores as do the moss plants, not by seeds as do the flowering plants. These facts will be made clear as we proceed with the study.

### **How do ferns reproduce their kind?**

**The spores** are borne on the fronds or sporophylls in cases called *sporangia* (Fig. 102). They may be attached in groups and covered with a fold of the edge of the leaf, or by a special structure developed for the purpose and called an *indusium* (Lat. *induere* = to put on). This indusium, together with the sporangia grouped under it, is called a *sorus* (pl. *sori*) which comes from the Greek and means a heap (Figs. 100, 101, 102).

**The sporangia** are discus-shaped structures borne on stalks. Around the outer edge of each sporangium is a ring of enlarged and thickened cells called the *annulus* (ring). (See Fig. 102.) When the spores are ripe the spore case opens on the side opposite the annulus; and by expanding and contracting under varying moisture conditions, the annulus lifts up the top of the spore case with some of the spores adhering to it. It is then snapped shut and the spores are thrown out. This is a means of spore distribution. The spores, however, are not thrown very far and all species do not possess the annulus on their sporangia. Compare this method of ejecting spores with that of the moss.

If a spore falls in a moist place it may germinate and develop into a scale-like, green structure which clings to the ground and sends rhizoids into it for salts and water. It is called the *prothallium* (Lat. *pro* = before + *thallus* = branch). It is usually heart-shaped, less than one half inch in diameter, and but one cell in thickness except in the middle. It has no roots, stem, or leaves and bears sperms and eggs. In these respects it resembles the gametophyte



FIG. 100.

FIG. 100.—Sori on the under surface of a fern frond. (*Gager.*)



FIG. 101.

FIG. 101.—An "x-ray" picture of two leaflets of the Boston fern, made by exposing a piece of photographic paper through the leaflets. The sori are seen as white spots on the leaf to the left.

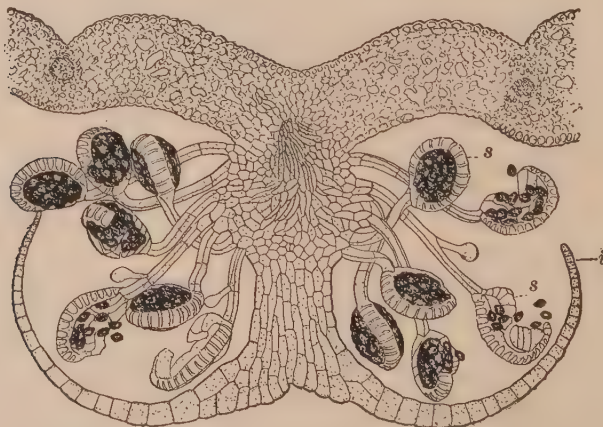


FIG. 102.—View of a section cut through a sorus to show the indusium (*i*) and the sporangia (*s*). Note the annulus on each sporangium and how they open and close to eject the spores. (*Bergen and Caldwell, after Engel and Prantl.*)



of the mosses and is the gametophyte generation in the life history of the fern. Fern gametophytes may often be found in green-houses in moist places where ferns are kept. They may be raised in

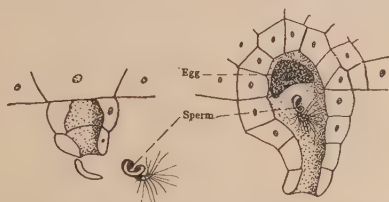


FIG. 103.—An antheridium on the left, and an archegonium on the right. A sperm is pictured leaving the antheridium, and one has entered the archegonium to fertilize the egg cell, which is somewhat triangle-shaped.

the laboratory by placing the spores of ferns on moist soil and keeping them covered with glass to prevent evaporation.

The archegonia and antheridia are rather degenerate structures and are found on the under side of the prothallium. Sperms and



FIG. 104.—Five drawings to show how a sporophyte grows from a prothallium. In 1, the sporophyte does not appear. In 5, it has developed three leaves. Note that it grows from the under side of the prothallium. (Gager.)

eggs are produced as in the moss, but the sperms are more complex in structure. They vary in different species, but in some forms they consist of a ribbon with a ball on one end and a group of long,

slender lashes at the other (Figs. 103 and 106). A sperm swims to an egg in an archegonium and fertilizes it. The egg then develops and puts forth, into the tissue of the prothallus, a foot which functions as a food absorber for a time; but soon a root and shoot are

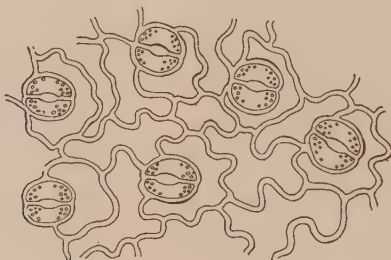


FIG. 105.—Stomates from the under surface of the frond of a fern. (Gager.)

formed, and the young sporophyte becomes independent. This independence is gained by the development of chlorophyll in its green fronds. The chlorophyll makes carbohydrates just as in other green plants. Stomates are present on the under side of the

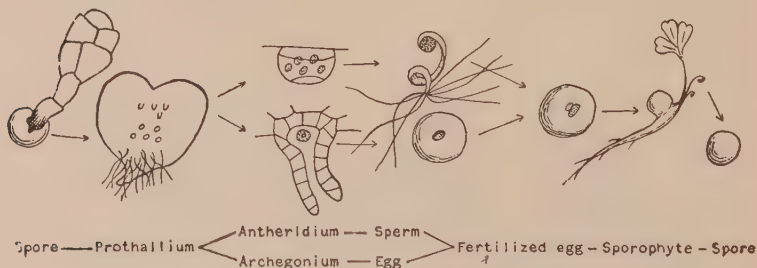


FIG. 106.—Life history of the fern.

leaf, and in all respects the fern leaf resembles the leaf of one of the higher forms of plant life. (See Figs. 104 and 105.)

### SUMMARY

Ferns are found in a great variety of situations but do not compete very successfully with flowering plants because they are less efficient in certain ways.

Ferns have stems and leaf stems which contain tubes for easy circulation of sap. They have good roots which also contain fibrovascular tissue. Their leaves are green and contain stomates through which gasses are taken in and given off easily.

The alternation of generations of ferns is similar to that of mosses but the relative prominence of the generations is reversed, and the sporophyte makes its own food.

**Review Questions.**—In what places may ferns be found? What are their leaves called? What are they called if they bear spores? In what special way are their stems better than moss stems? Compare the sporophytes of ferns and mosses. Compare the gametophytes. Where do ferns bear their sporangia? How are spores expelled from their spore cases in some ferns? Where are the antheridia and archegonia found? Compare them with those of the moss. What is the function of the foot of the sporophyte? Describe the leaf of the fern.

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Work.**—The life history of the fern may be studied from charts, lantern slides, microscopic slides, and actual material.

Try to raise some ferns from their spores.

**Blackboard Work.**—Complete the following table which compares mosses and ferns.

| Comparison       | Moss             | Fern |
|------------------|------------------|------|
| Stems.....       | No ducts         |      |
| Leaves.....      | No stomates      |      |
| Roots.....       | Absent           |      |
| Gametophyte..... | Prominent        |      |
| Sporophyte.....  | Small, not green |      |

### References

- Bergen and Caldwell, *Practical Botany*, Ginn & Co.  
 Gager, *Fundamentals of Botany*, P. Blakiston's Son & Co.  
 Transeau, *Science of Plant Life*, World Book Co.  
 Gager, *Heredity and Evolution in Plants*, P. Blakiston's Son & Co.  
 Clute, *Our Ferns in Their Haunts*, W. N. Clute & Co.

## PROBLEM 6. HOW ARE FLOWERING PLANTS ADAPTED TO SEED PRODUCTION?

**General Questions.**—How does the number of kinds of flowering plants compare with the number of other kinds of plants? Which are the most useful to us? Why are they called seed plants? What is the structure of a typical flower? How do the spores of flowers differ from the spores of ferns? Is a pollen grain a spore or a sperm? What are the functions of each of the parts of a flower? Of what advantage is color? Perfume? Nectar? What is cross-pollination? What is meant by self-pollination? How are hybrids produced?

When we think of a plant, is it not a flowering plant that comes to our mind? If we look at plants in nature are they not nearly all flowering plants? There are some exceptions to this. It would not be true if we lived in a pine forest or in a grassy prairie, but even the pine forest would have hundreds of kinds of flowering plants growing within it; and the grass of the prairie has flowers in a botanical sense, but not in the ordinary meaning of the word flower.

The flowering plants live in all kinds of places where green plants can grow and dominate the plant life of the earth. Nearly all of our farm and garden plants are flowering plants—if we class the grains and grasses with them.

**Seed plants** is a term which may frequently be used instead of the term “flowering plants”, but it includes the grasses, palms, and pines and their allies. Grasses, grains, and palms have flowers, but they are very seldom showy and go unobserved. Pines belong to a great group of plants which bear their seeds in cones. They are true seed plants, but we do not consider the pine cone a flower, and they are never called flowering plants.

**What part does the flower play in the life history of seed-plants?**

The **complete flower** consists of six parts; *pedicel*, *receptacle*, *calyx*, *corolla*, *stamens*, and *pistil*. Fig. 107 is a diagram of a complete flower. The essential structures are the stamens and pistil, and the flower is said to be *perfect* if it has these, whether the calyx and corolla are present or not. This is because the flower can do its work if these two are present. A *complete* flower contains all of the

parts which are shown in the diagram. Study this diagram carefully and be able to reproduce it from memory.

The parts of the *calyx* are arranged in a circle and usually consist of three, four, or five green, leaf-like structures which protect the bud before it opens, and are called *sepals*. The showy part of the flower is the *corolla* which is usually colored and corresponds in number of parts and arrangement to the sepals. It is more apt to vary than the calyx, and is often a double circle or may not be symmetrical as we shall see. Its parts are called *petals*. They may be more or less united together to form a tube—as in the morning-glory, gourd,

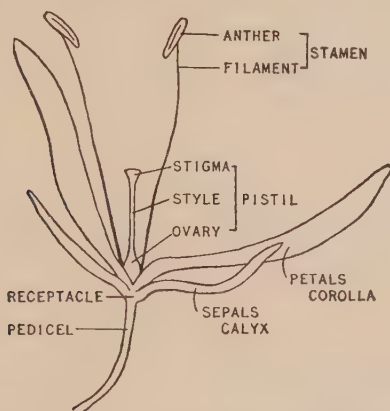


FIG. 107.—Diagram of a flower to show its six parts and their subdivisions.

pumpkin, four-o'clock, and flax. They may be of a different shape on one side of the pistil from what they are on the other as in sweet peas, orchids, and violets. They may be very much reduced in size as in many weeds. Some folks do not know that flowers are present in such plants. (See Figs. 108, 109, and 120.)

Stamens are also arranged in one or more circles. They bear *pollen* in the little boxes at their ends. Pollen grains are spores, and the stamens may be called *sporophylls* as we call the spore-bearing structures in the fern, and to which stamens correspond. The common names for the parts of a stamen are *filament* and *anther* as they are illustrated in the diagram of a flower (Figs. 107 and 108).



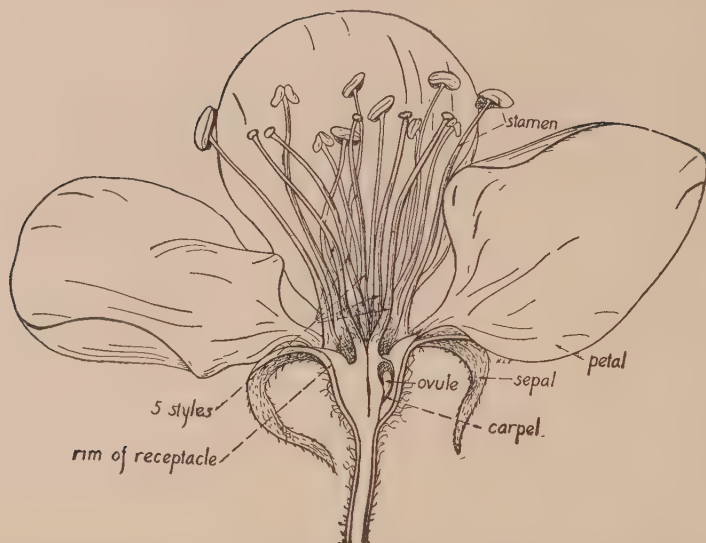


FIG. 108.—Section through an apple blossom to show its parts. The pistil is divided into five styles and stigmas. Each has a carpel forming the walls of a locule at its base. The carpels comprise the core of the apple. (*Robbins.*)



FIG. 109.—Water lily flower to show the gradual change from sepals to petals and to stamens. Note that some of the petals have anthers on their tops showing that they are both petals and stamens. (*Bergen and Davis, after Brown, Principles of Botany; Ginn & Company.*)

**Pollen grains** are of many shapes and forms. It will be interesting to view various kinds with the aid of the microscope. The color of pollen is also variable. It may be black, red, brown, and white, but is usually yellow.

**The pistil**, when mature, bears the seeds and is composed of one or more parts called *carpels*. These divisions correspond to stamens in the circle which we just described. They also bear spores, but their spores are never seen except by the use of the microscope, because they are enclosed within the pistil.

**Spores** of flowering plants are of two kinds, pollen grains being smaller are transported through the air by wind or insects; but the spores in the carpels are large and are never transported. This situation is more complicated than in ferns where there is but one kind of spore which is produced on the leaf or sorophyll.

**Seeds** develop in the base of the pistil in chambers within the carpels. These chambers are called *locules*. The seeds are attached to the walls of the locules in certain areas called *placentas*. (See Fig. 108.)

A normal pistil is composed of three parts: The base, which contains the carpels, is called the *ovary*; a moist, or feathery, surface for the reception of pollen is called the *stigma*; and a part connecting the ovary and stigma is called the *style*.

Sepals, petals, stamens, and carpels are modified leaves serving the function of reproduction. (See Fig. 109.) The change from sepals to stamens is gradual in the water lily, a complete flower of many circles; as is shown in the figure. The carpels of almost all flowers have suffered greater change than any other parts, but still retain a leaf-like appearance in the pea pod, milkweed pod, and the columbine pod. (See Figs. 116 and 125.)

**Pollination.**—The pollen which is produced in the anther must be carried to the stigma of the same flower (or as is more often the case to the stigma of another flower of the same species) or the seeds can not form. Pollen is carried in three ways: namely, by *water*—in the case of a few water plants, by the *wind*, and by *insects* or other flower-visiting animals. Flowers which do not have showy petals have feathery or spreading stigmas and are dependent upon the wind for carrying their pollen. Grains, grasses, and sedges are examples.

A very interesting relationship exists between insects which visit flowers and the flowers which they frequent. Each group is dependent on the other for existence.

The showy petals and perfume aid insects in finding flowers. Practically all flower-visiting insects can distinguish colors and have a well developed sense of smell. The nectar which is secreted by glands near the base of the pistil serves as food for many insects. Thus, we see that *color*, *perfume*, and *nectar* have been developed in flowers in connection with pollination.

Some plants produce flowers which never open and are consequently self-pollinated. In the violet they are produced after those which blossom in the spring have ceased to open. Few people know about these flowers. Perhaps the violet has developed this habit because its showy flowers would be difficult for insects to find in the tall vegetation which covers the plants at that season (Fig. 110). One of the milkworts (*Polygala polygama*) bears both open and closed flowers at the same time. The closed ones are beneath the surface of the soil. *Lamium*, a mint, produces closed flowers in



FIG. 110.—Summer flowers of the violet which do not open and have no showy petals. 1, a bud; 2 a flower; 3, a seed capsule; 4, an open seed capsule. This is the common blue violet. The flowers were produced indoors, in the fall of the year, and were not buried as they are in some violets.

the spring and fall, and open ones in the summer.

**Hybrids.**—Pollen which is produced by one kind of plant will not usually fertilize a flower of another species; but if the two species

are closely related, or if the two plants are varieties of the same species, the pollen may function. The offspring of such a union will possess characteristics of both parents and is called a *hybrid*. It is well known that if various kinds of squashes, pumpkins, and gourds are grown together; and the seed from the fruit is saved and planted the next year; many varieties of hybrids will be produced, few or none of which, however, will be of any value. Although most hybrids are worthless, many new and valuable varieties of agricultural plants have been produced by intentional or accidental cross-pollination between nearly related plants. We will have more to say about this when we study plant breeding. (See Fig. 191.)

### OUTLINE-SUMMARY

Flowering plants are the most important kinds of plants.

The parts of a complete flower are, pedicel, receptacle, calyx, corolla, stamens, and pistil. The stamens and pistil are essential.

Structure and use of each of the above named parts.

Pollination may be accomplished by wind, water, or insects, and is aided by color, nectar, and perfume in many flowers.

The violet and some other plants have special flowers in which pollen is not transferred from flower to flower.

Hybrids are produced from seeds which have grown from cross-pollination between plants which are not of the same kind.

**Review Questions.**—Are all seed plants flowering plants? Make a diagram of a complete flower and label all parts from memory. What do pollen grains look like? In what part of the flower are seeds developed? How may pollination be accomplished? Describe the summer flowers of the violet. How are hybrids produced?

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Work.**—At least one flower should be drawn and carefully labeled.

Examine various examples of monocotyledonous and dicotyledonous flowers and note the distinctions. Let each student who can, bring one or more specimens to the class.

Try to secure some examples of flowers which are water, wind, and insect pollinated. Compare their stigmas.

## References

Densmore, *General Botany*, Ginn & Co.

Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co

## PROBLEM 7. HOW ARE SEEDS PRODUCED?

**General Questions.**—Why are flowering plants called angiosperms, and pines gymnosperms? How do pollen grains germinate? How does the pollen grain aid in producing a seed? How does the ovule develop a seed? How is endosperm formed? Of what use is it to the growing seed? Why is endosperm not present in some mature seeds?

It is always a surprise to one when he is informed for the first time that flowering plants have gametophytes, sperms, eggs, and spores as do the mosses and ferns. In the production of seeds, however, the flowering plants are superior to any of the lower forms; but seeds can not be produced without going through the cycle of an alternation of generations as does the fern. The study of the process by which plants produce seeds is one of the most interesting of all botanical problems.

The flowering plants are called **ANGIOSPERMS** (meaning covered seeds) because their seeds are inclosed in an ovary. The pines and their allies are called **GYMNOSPERMS** (meaning uncovered seeds) because they bear their seeds on the surface of the scales of cones. There is really very little difference in the life history of the two groups. The stamens and carpels, as well as the scales of pine cones, are modified leaves which bear spores and are called *sporophylls* as are the spore-bearing leaves of ferns.

**Spores** of seed plants are of two sizes, in contrast to the mosses and ferns where each plant produces only one kind of spore. Pollen grains are the small spores and are called *microspores*, from "micro" which means small. The other kind of spores are larger and are called *megaspores*, from "mega" which means large. The megaspores are produced within the carpels in little structures called *ovules*. (An ovule is shown in Fig. 111.) They were called this by the botanists who discovered them because they thought they were little eggs. We know now that they are not eggs, but that an egg-cell is developed within the ovule, as we shall see.



If you will study the illustration of the ovule of the pine cone, you will note that it is surrounded by the seed coats. They grow around a central part called the *nucellus*, but do not completely enclose it. A round opening is left on one side. It is called the *micropyle* (little gate) and receives the pollen tube in fertilization. The megaspore is formed in the tissue of the nucellus. Because it contains the megaspore, the ovule may be thought of as a spore case and corresponds to the anther of the flower, which bears the spores called pollen.

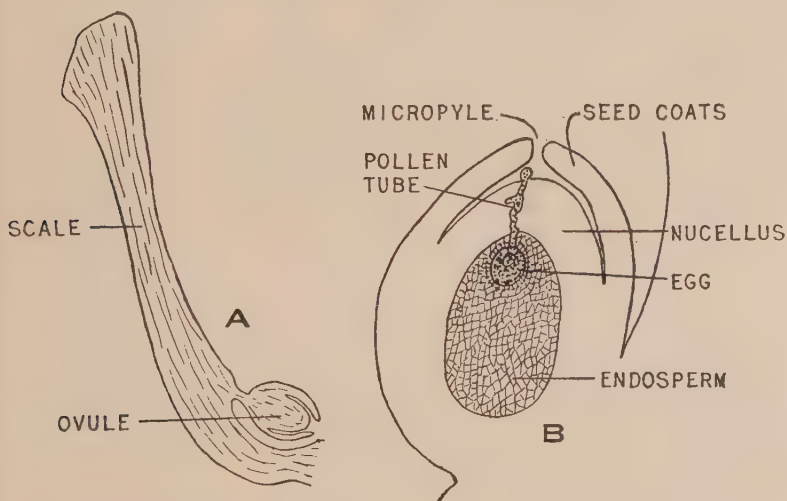


FIG. 111.—Two ovules of the pine. A, a scale of the female cone at the time of pollination. The ovule contains a megaspore (not shown). B, the ovule at the time of fertilization. The endosperm is the female gametophyte, and the pollen tube is the male gametophyte. Note that the cone has reversed its position so that the ovule opening points upward.

**Gametophytes of flowering plants** grow from spores as they do in ferns and mosses, but there are two kinds of gametophytes. One develops from the microspore (pollen grain) (Fig. 112), and is the pollen tube. The other develops from the megaspore within the ovule, and is called the *embryo sac* (Fig. 113) because it forms a sac in which the embryo of the seed develops. We will describe the development of the male gametophyte first.

**Pollen grains** are of various shapes and sizes. When one falls on the stigma it absorbs moisture by osmosis and begins to germinate. A tube grows forth from it and penetrates the tissue of the stigma and style by dissolving it.

Before the pollen grain is shed from the anther it has begun its development and two nuclei are formed. One of them occupies a position in the end of the pollen tube and is called the *tube nucleus*. The other follows closely and is called the *generative nucleus*. It soon divides to form two *sperm nuclei* which function in fertilization.

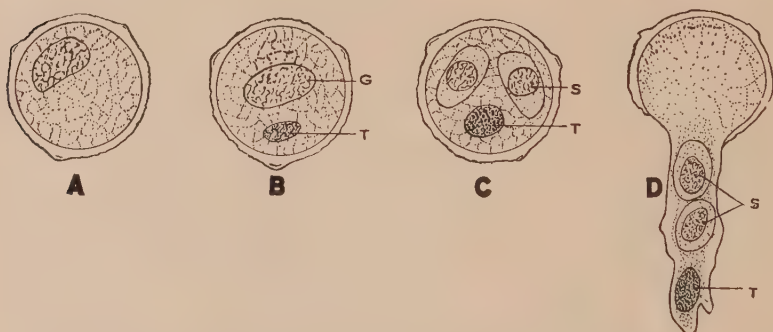


FIG. 112.—Development of the pollen grain (male gametophyte). A, the pollen grain with one nucleus; B, the first step in the development of the gametophyte. The nucleus has divided to form a generative nucleus (G) and a tube nucleus (T); C, the generative nucleus has divided to form two sperm nuclei (S); D, the pollen grain has germinated and put forth a tube, and the nuclei have passed down into it.

The pollen grain may be looked upon as a male gametophyte at any time after it has begun to develop (even before it is shed from the anther), and the pollen tube corresponds to an antheridium which produces only two sperms.

**The pollen tube** traverses the entire length of the style in a very short time, and enters a locule of the ovary. It usually grows along the carpel wall and enters an ovule through the micropyle. It finally reaches the female gametophyte by dissolving its way through the nucellus. Pollen tubes are always microscopic in size, and very little was known about fertilization in flowering plants until the use of the microscope had become highly developed.

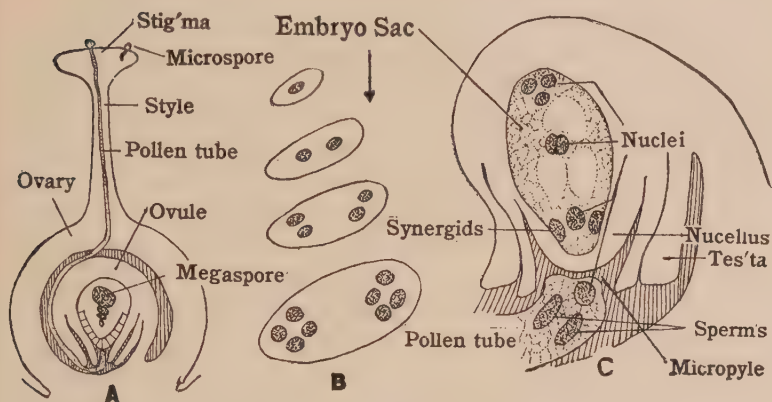


FIG. 113.—Development of the embryo sac (female gametophyte). *A*, a section through a pistil showing a single ovule in the locule of the ovary. *B* shows the development of the eight nuclei in the embryo sac. *C* shows the mature female gametophyte and the tip of the male gametophyte (pollen tube), the former containing eight nuclei and the latter containing only three.

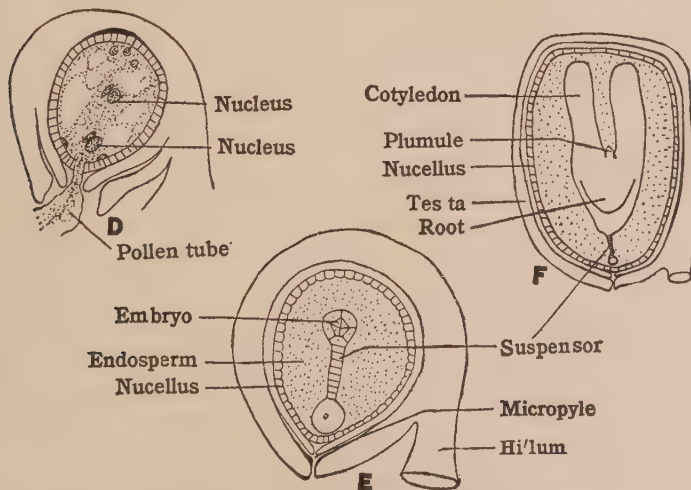


FIG. 114.—Development of the embryo. This figure is a continuation of the preceding. *D* shows the antipodal cells disappearing, and the fusion of the two sperms with the endosperm nucleus and the egg nucleus. *E* shows the developing embryo with its suspensor and the endosperm. *F* shows the young embryo and its parts.

**The Growth of the Embryo Sac.**—During the growth of the pollen tube within the nucellus, the megaspore develops into a female gametophyte; but it is very degenerate (Figs. 113 and 114). When mature it contains only eight nuclei,—developed as follows:

The megaspore draws nourishment from the tissue of the nucellus, enlarges, and its nucleus divides (see diagram). Each nucleus moves to an opposite end of the megaspore tissue which is now known as an *embryo sac*. (It received this name because the embryo ultimately develops within it, and because at the time it was named, its nature was not understood.) Each nucleus then divides twice forming eight cells—four in each end (B). Three of the four in the end which is usually opposite the micropyle of the ovule are called *antipodal nuclei* and soon degenerate. The other moves to the middle of the embryo sac and here meets one of the four from the other end, and fuses with it. Of the three left in the end near the micropyle two are called *synergids* (helper cells) and are thought by some investigators to guide the sperms from the pollen tube when they enter the embryo sac. They may be degenerate egg cells or the remains of a degenerate archegonium. The other of the four nuclei in this end is an *egg nucleus*, and fuses with one of the sperms from the pollen tube. This fertilized egg develops into the embryo of the seed.

**The Growth of the Endosperm.**—The second sperm of the pollen tube passes to the middle of the embryo sac and fuses with the pair of nuclei there, which have come from opposite ends of the embryo sac. This constitutes a triple union of nuclei and is known as *double fertilization*. It is unknown outside of the angiosperms, and probably originated among them as a result of the natural tendency of reproductive cells to conjugate. This nucleus, with a triple origin, develops, by a continued cell division, into a cellular tissue in the young seed which is called the *endosperm*, hence the triple nucleus is called the *endosperm nucleus*. (See Figs. 113 and 114.)

**The developing embryo** lies in the endosperm (Fig. 114, F) and draws its nourishment from it. In some seeds—as the bean, pea, and squash, the endosperm is practically all absorbed by the time the seed is ripe; in others—as the grains, castor-oil plant, and poppy,

the endosperm is found in considerable quantity in the mature seed, and is absorbed during the early life of the seedling after the seed germinates.

It should be kept clearly in mind that the embryo is the young sporophyte, and possesses a root, a stem, and leaves. It is a resting stage in the life history of the plant, and serves to preserve the life of the plant during an unfavorable period (as winter) as well as to reproduce the plant.

It should be interesting at this point to recall that the thrifty, green gametophytes of the moss are still represented in the flowering

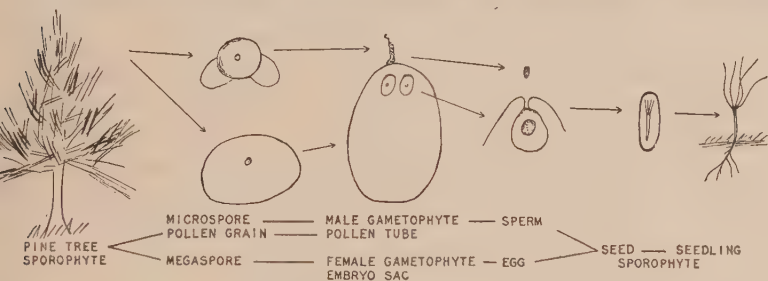


FIG. 115.—The life history of the pine. Compare with the diagrams of the life history of the fern and moss. Note the effect of two kinds of spores in the seed plants.

plants by the degenerate pollen grain and its tube, and the embryo sac. The well developed antheridia and archegonia of the moss have ceased to be cellular in structure or to be recognizable as organs. On the other hand, the moss sporophyte which was parasitic upon the gametophyte has become, in the seed plants, the stately pine, giant oak, and beautiful lily. Compare Figs. 106 and 115.

### SUMMARY

Flowering plants bear their seeds enclosed in developed ovaries, but pines bear them in the scales of cones.

Flowering plants produce small spores which develop into pollen tubes, and large spores which develop into embryo sacs.

The pollen tube is a male gametophyte and produces two sperms. The embryo sac is a female gametophyte and produces eight cells



one of which is an egg-cell, and one forms an endosperm nucleus after triple fertilization.

In the angiosperms, the endosperm is a cellular growth and furnishes food for the growing embryo. After beginning its growth, the embryo rests, the seed coats dry, and the seed is complete.

**Review Questions.**—Compare the method of producing seeds in angiosperms and gymnosperms. Describe the two kinds of spores which are produced by seed plants. How does their production differ from spore production in ferns? What develops within an ovule? Why was it so called? How may an ovule be compared with a stamen? Which produces the greatest number of spores? Which the larger? Describe the growth of a pollen tube. Where do you suppose it gets its food? Describe the growth of the embryo sac. What becomes of each of its eight cells? How is the endosperm nucleus formed? What is the work of the endosperm? What advantages are gained by the production of seeds?

### SUGGESTIONS

This is a difficult study, but a very valuable one. If diagrams of life histories of mosses, ferns, and seed plants are placed on the blackboards while instruction and recitation work is going on, it will be helpful. Microscopic work on the sectioned ovary is of doubtful value. Pollen grains may be viewed to advantage.

### References

Bergen and Caldwell, *Practical Botany*, Ginn & Co.  
Bergen and Davis, *Principles of Botany*, Ginn & Co.  
Densmore, *General Botany*, Ginn & Co.

### STUDY 8. FRUITS AND THEIR ADVANTAGES TO PLANTS

**General Questions.**—What are fruits? When the botanist thinks of a fruit, does he have in mind the same thing as the gardener would? How may fruits be classified? What are the advantages of dry fruits? What are the advantages of fleshy fruits? Why are fruits distributed?

It is a simple matter to figure on paper that some plants are capable of producing as many as a million spores or seeds in a season. How many plants of these species would there be if all seeds grew

to maturity each year! Let us suppose that an oak tree produces 5,000 acorns and that they all fall directly from the tree to the ground and that they all sprout the following spring. They would all require the same food from the soil, the same amount of water, and would seek sunlight in the same way. The parent tree would compete with them in all of these particulars, and probably none of them would grow to be trees.

Would it not be much better if they could be scattered over a wide area, where they would come into all kinds of competition, in all kinds of environments? Truly some of them would meet severe competition and perish; but some would be fortunate, and grow in places where they could successfully compete with other plants and live. Competition between like kinds is more severe than between different kinds, because plants of the same kind require the same living conditions.

We shall see in this study how plants have solved the problem of distributing their seeds through the agency of their fruits. They have not all adapted themselves in the same way, nor are all of their methods equally efficient, but in some way or other all plants must have their seeds distributed to new localities to avoid competition among themselves and to seek out new localities in which to grow.

### **What part do fruits play in the life history of plants?**

To the botanist a *fruit is the growth which results from the fertilization of a flower*. It may be simply the ripened ovary, called the *pericarp* (Gr. *peri* = about + *karpōs* = fruit), and the seeds within it. In many of the domestic fruits the calyx and receptacle are included in the growth and form a part of the fruit. To the gardener tomatoes and squashes are vegetables; to the botanist they are fruits.

**Fruits may be classified** as *dehiscent* and *indehiscent* according to whether they dehisce (open) or not. The dehiscent fruits may be discussed under four heads: namely,—*legumes*, *follicles*, *siliques*, and *capsules*.

### **DRY FRUITS**

**The legume** is a pod, well illustrated in the pea and bean; and consists of a single, long carpel folded along its midrib so as to inclose

a single locule. The seeds are alternately attached to each side of the carpel along the midrib. It splits open along both edges when ripe, and in some forms each half curls in such a way that the seeds are thrown to some distance.

**The follicle** is a pod which differs from the legume in that it opens along only one edge. It is well illustrated in the monkshood and columbine.

**The silique** resembles the legume but contains a partition as in cabbage or mustard.

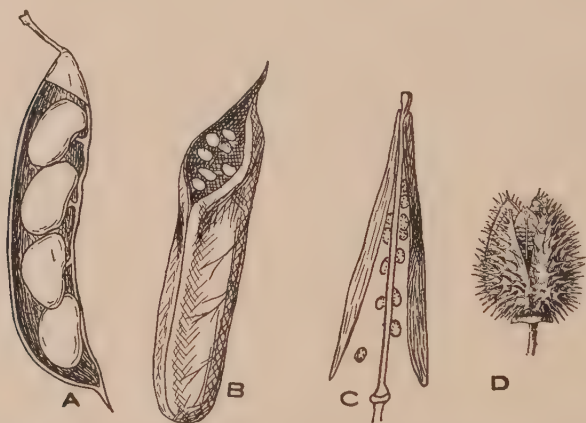


FIG. 116.—Four dehiscent fruits. A, pod of lima bean which is a legume; B, follicle of monkshood; C, silique of mustard; D, capsule of jimson-weed.

**The capsule** is a compound ovary consisting of two or more carpels and opens in various ways. It is illustrated in the morning-glory poppy, and jimson-weed. Many capsules retain their seeds for a considerable time, and when they are shaken by the wind or passing animals, the seeds are shaken out. Practically all dehiscent fruits are dry when ripe. (See Fig. 116.)

**The indehiscent fruits** may be divided into two groups: namely, those which are *dry* when ripe and those which are *fleshy*. The *dry indehiscent* fruits may be discussed under five heads as follows: *akenes*, *grains*, *nuts*, *samaras*, and *loment*s.

## FRUITS WHICH DO NOT OPEN

**The achene** is illustrated in the buttercup, wood anemone, sunflower, and dandelion. It consists of an entire pistil, does not open, and contains only one seed. In the *COMPOSITÆ* family (dandelion and thistle) the fruit develops from an inferior ovary and the calyx may persist as a tuft of hairs which act like a parachute when the fruits are distributed by the wind.

**The grains** are illustrated in all of the grains and grasses. They resemble achenes, but the seed coats are firmly fused with the wall of the ovary which is comparatively thin. In the achene a space exists between the seed coats and the ovary wall. Achenes and grains are usually called seeds. They really are more than seeds; they are entire, one seeded fruits. Popular usage, however, permits

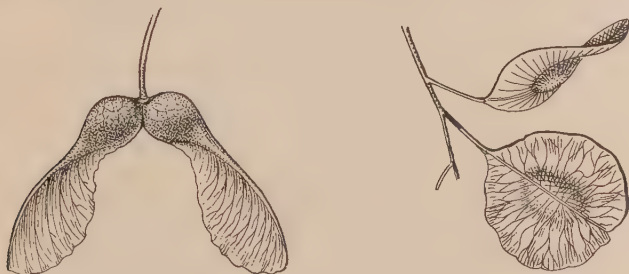


FIG. 117.—Samaras of maple (left) and elm (right). (*Jenkins.*)

the use of the word *seed* in referring to them, but the student should understand that they are fruits.

**The nuts** are also very much like achenes, but are larger. They are usually partly or entirely enclosed in an involucre (leaf-like covering) from which they separate when ripe. The prickly hulls of chestnuts and beechnuts, the cups of acorns, and the leafy hulls of the hazelnuts are involucres. The Brazil nut and almond are not nuts. The former is a seed, and the latter is the inner wall of a stone fruit or drupe. How are nuts distributed in nature?

**The samaras** are winged fruits, and are illustrated in the elm, ash, ailanthus, and various maples. The seed of the pine is also winged and resembles the fruit of the maple, but it is not a fruit;

it is a seed. The entire pine cone is a fruit. Many of the winged fruits spin as they fall. Let some maple fruits or some pine seeds fall, and watch them spin. Winged fruits and seeds are distributed by the wind. (See Fig. 117.)

**The loment** is the fruit of the sticktights. It is a legume which is divided into sections. It does not open, but each section containing



FIG. 118.—A loment, or sticktight, of one of the legumes. Note that it has been developed from a legume pod.

one seed is separated when ripe. They are covered with small hooks which fasten into the hair of passing animals, thus providing for the distribution of the fruit. Various fruits, of many kinds, are provided with hooks, and are distributed as are the sticktights. They are commonly known as *burs*, and occur in the hound's-tongue burdock, sand-bur, and cocklebur. (See Figs. 118, 119, and 129.)



The structure of fleshy fruits depends largely upon the arrangement of the parts of the flower from which they come. In such flowers as the apple, squash, pumpkin, rose, and gooseberry the ovary is sunk deep into the receptacle, and the calyx is brought up above the ovary in such a manner that the sepals and petals are



FIG. 119.—A cluster of ripe cockleburs in the fall of the year.

attached to its upper part (Fig. 120). Such flowers are said to be *superior*, and the ovary is *inferior*. In flowers like those of the peach, cherry, blackberry, and bean the calyx is attached to the base of the pistil. These flowers are *inferior*, and the ovary is *superior*. Fruits developed from inferior ovaries contain part of the receptacle

and calyx. Those developed from superior ovaries do not contain any part of the calyx but may contain a part of the receptacle.

The flesh of fleshy fruits is eaten by birds and animals. The seeds are often bitter, and are usually not eaten. If they are they usually pass through the body undigested. The seeds of many berries are scattered over wide areas in this way by birds. In your walks through the country note the large number of plants bearing fleshy fruits that are found along fence rows. How did they get there?

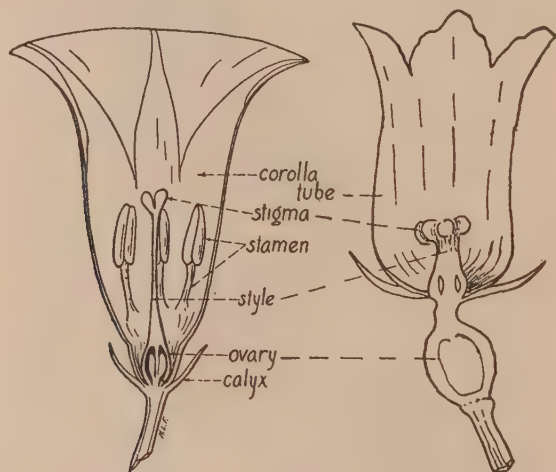


FIG. 120.—Flower of sweet potato (left) and squash (right) to show superior and inferior ovaries. Note that no part of the calyx enters into the growth of the fruit in the sweet potato, but that it has grown completely around the ovary in the squash. (*Sweet potato is from Robbins.*)

### FLESHY FRUITS

THE SIMPLE FLESHY FRUITS may be discussed under five heads as follows: *berry*, *pepo*, *hesperidium*, *pome*, and *drupe*.

**Berries**, botanically speaking, are of two kinds: those that contain part of the calyx; as the gooseberry, currant, huckleberry, and banana; and those that do not contain any part of the calyx; as the tomato, grape, and persimmon. The berry is rather thin skinned, and contains several or many seeds. It is usually a fleshy, compound or many loculed ovary.

**The pepo** is a fruit of which the rind is derived from the calyx of the flower. It occurs in cucumbers, melons, gourds, squashes, and pumpkins. It results from the development of an inferior ovary; and may be solid as in the watermelon, or hollow as in the muskmelon. (See Fig. 120.)

**The hesperidium** is a thick walled, many carpelled ovary. Oranges and lemons are examples. Both the pepo and hesperidium are special modifications of the berry.



FIG. 121.—A complex fleshy fruit. Each raspberry fruit develops from one blossom. It is an aggregation of fleshy carpels. (*U. S. Dept. of Agriculture.*)

**The pome** is illustrated in the apple, hawthorne, pear, and quince. It results from the development of an inferior ovary with several—usually five—locules inclosed by heavy carpels, constituting a core. The greater part of the fruit develops from the calyx and receptacle. The fruit of the rose is called a *hip* and is similar to the pome, but the hard core does not occur. The core and seeds are usually rejected when these fruits are eaten. In this way they are distributed.

The **drupe** is often called a stone fruit. The peach, plum, almond, cherry, and black haw are drupes. It is a ripened ovary containing no part of the calyx as does the pome. It normally contains one seed surrounded by the inner wall of the pericarp (carpels), which is hard, and an outer pulpy wall. When the flesh is eaten the hard

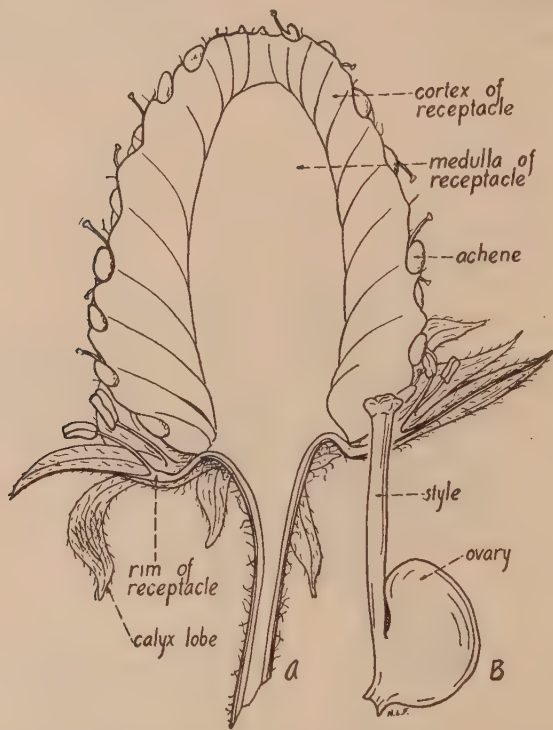


FIG. 122.—Section through the fruit of the strawberry to show that it is a fleshy receptacle with achenes on its surface. *B* is an enlarged view of a style and ovary from which an achene develops. (Robbins.)

stone is usually rejected, and if dropped in a favorable locality may reproduce the plant.

THE COMPLEX FLESHY FRUITS may be grouped under three heads: namely *aggregate fruits*, *accessory fruits*, and *multiple fruits*.

In the **aggregate fruits** of the blackberry and raspberry, each seed is surrounded by a pericarp exactly like a drupe, and these

little *drupelets* are united to a common receptacle. In the blackberry the receptacle is a part of the fruit. In the raspberry it is not (Fig. 121).

In the **accessory fruit** of the strawberry, the receptacle forms the fruit. The seeds are dry achenes on its surface (Fig. 122).

In the **multiple fruits** of the mulberry and pineapple, many flowers are fused into one fruit-mass. The pineapple has lost its seeds due to selective breeding and cultivation. The cone of the pine may be considered a multiple dry fruit. Why are fleshy fruits usually hard seeded, bitter or sour before ripe, and highly colored when mature?

### SUMMARY

The special shape and form of a fruit is usually associated with its distribution, or with the distribution of its seeds.

The classification of fruits is given in the table below.

#### CLASSIFICATION OF FRUITS

| Dehiscent | Indehiscent |               |                |
|-----------|-------------|---------------|----------------|
| legumes   | <i>Dry</i>  | <i>Fleshy</i> |                |
| follicles | achenes     | <i>simple</i> | <i>complex</i> |
| siliques  | grains      | berry         | aggregate      |
| capsules  | nuts        | pepo          | accessory      |
|           | samaras     | hesperidium   | multiple       |
|           | lomentis    | pome (hip)    |                |
|           | burs        | drupe         |                |

**Review Questions.**—If a plant produced a million seeds per year and they all lived, how many would there be in ten years, if they were annuals? If each plant weighed 5 pounds, how many pounds? If we allow each plant four square feet of space for convenient growth, how much territory will they occupy? Why must the seeds of plants be distributed? Refer to the table in which fruits are classified and tell how each type of seed may be distributed.



## SUGGESTED SPECIAL ACTIVITIES

**Museum Project.**—Make collections of various types of fruits. Study them mount them properly, and preserve them for the museum.

**Laboratory Study.**—Draw specimens of types of fruits in outline and section.

## References

Peterson, *How to Know the Wild Fruits*, Macmillan Co.

Robbins, *Botany of Crop Plants*, P. Blakiston's Son & Co.

Jenkins, *Interesting Neighbors*, P. Blakiston's Son & Co.

Atwood, *Problems, Projects, and Experiments in Biology*, P. Blakiston's Son & Co.

## PROBLEM 9. BY WHAT AGENCIES ARE SEEDS DISPERSED?

**General Questions.**—Do plants throw their seeds? If so, how do they do it? Is this a common practice? How may wind distribute seeds and fruits? How may water distribute seeds and fruits? Do animals distribute seeds? If so, do they derive any benefit from it? How does man rank as a distributor of seeds?

We have seen the remarkable adaptations of some fruits for the distribution of seeds, but we have not considered the agencies which carry the seeds. Fortunately for plants, there are five classes of agencies at work in the distribution of plant seeds. Some of these agencies distribute both seeds and fruits.

When Australia and New Zealand were discovered, it was soon observed that practically none of the plants and animals which are common in other parts of the world were found there. We may wonder why this was true, and at that time many reasons were suggested as solutions of the problem. As time went on a great experiment in distribution was carried on. It was soon learned that rabbits, foxes, rats, sheep, clover, vegetables, and fruits were not absent because they could not live in that climate, for when they were taken there, they lived well.

So it came to be known that the reason sought was very simple. It was because they had never been brought there. It is now well known that plants and animals come into new situations, or reestablish themselves in old ones from which they have been eliminated, by some means of distribution. In this study we will consider the

agencies of distribution and some of the more interesting adaptations of plants to them.

**I. Flastic Mechanisms** have been developed in many plants to accomplish this end. The cranesbill throws its seeds some distance by the valves (carpels) of the fruit springing up when dry, and throwing out the loosely held seeds. Nearly everyone knows the



FIG. 123.—Capsules of evening primrose (left) and butter and eggs (right). These capsules retain their seeds after they are ripe and permit them to be shaken out a few at a time. Is this better than dropping them all at one time?

touch-me-not for its peculiar method of throwing out its seeds from the capsule when touched.

Morning-glories, evening primroses, the mullein, and the jimson-weed hold their seed in capsules, and so do not shed them all at one time. Animals in passing may bend them down, and on springing up the seeds are thrown out. Some seed cases of this type may hold their seeds all winter. (See Fig. 123.)

The stroller in the woods in early autumn is familiar with the popping of the witch hazel seeds from their opening seed cases. The fruit of the sand-box tree of tropical America explodes when dry with a report like that of a pistol. The fruit of the squirting cucumber is very much inflated when ripe. When it falls from the plant, the end of the stem pulls out of the tissue of the fruit leaving a hole through which the contents of the fruit, including the seeds, squirt with considerable force (Fig. 124). Other plants with elastic



FIG. 124.—The squirting cucumber (*Echium*) discharging its seeds as it breaks from its fruit stem. (Jenkins.)

mechanisms for seed dispersal which may be investigated by the class are the pansy, violet, Jersey tea, wild balsam, and herb Robert.

**II. Wind Distribution.**—Perhaps the most remarkable and successful dispersion adaptations are those that occur in connection with wind distribution. The samaras of the ash, elm, and maple have been mentioned in the discussion of fruits. The seeds of the catalpa, pine, and trumpet creeper are winged, and are carried by the wind much as are the above mentioned fruits. Winged seeds may be carried many rods before a strong wind.

The achenes of the thistle, dandelion, and lettuce were also mentioned in the study on fruits. The seeds of cottonwood and the milkweeds are supplied with hairs, and are carried by the wind as



FIG. 125.—Milkweed pods and their tufted seeds. Note how the pod opens to let the seeds out.

are the tufted achene fruits. Such structures are often carried up to great heights, and may be carried many miles before a strong wind. (See Fig. 125.)



FIG. 126.—Cocoanut trees growing on the shore of an island in the South Seas. The cocoanut is able to germinate in comparatively dry soil, as the sand of the sea beach, because it is provided with its supply of water in the form of "milk" within the nut. (*Jenkins.*)



Some structures are rolled over the ground by the wind, and scatter their seeds as they go. Tickle grass (*Panicum capillare*) and squirrel-tail grass (*Hordeum jubatum*) break off below the flower clusters and roll before the wind. The grains loosen, and come off as they go. The awns of squirrel-tail grass may cling to passers by, and be dispersed in this way also. The common tumbleweed (*Salsola*), peppergrass (*Lepidium*), and others break off at the ground and roll about over the fields until snow falls. The Russian



FIG. 127.—A yellow water lily, *Nelumbo lutea*, showing its peculiar seed capsule. It may also propagate itself by tubers. Two of these are shown in the illustration.

thistle tumbleweed may even cross fences by being piled up along the fence until the level of the top is reached, then those coming afterward roll up the incline over their comrades, and the fence is passed! A large plant may carry 200,000 seeds, and scatter them over a great area. (See Fig. 238.)

**III. Water Distribution.**—The seeds of many water plants float on the water, and under the influence of the wind or currents may be carried to a new location. Plants of many kinds are apt to spring up on the shore line of a pond or on a newly formed island.

The fruits of the cocoanut are believed to have been carried to many uninhabited islands by floating on the ocean. The top-shaped fruits of a yellow water lily bend over and drop some of their nut-like seeds to the bottom of the water when they are ripe. Others are retained in the capsule which floats away, thus the species is maintained in its position up-stream, and the current or wind may carry the capsule to a new locality. (See Figs. 126 and 127.)



FIG. 128.—A cluster of elderberries. They are distributed by birds. On your field trips note how often you see elderberries growing along fence rows and other places where birds are apt to alight.

**IV. Distribution by Animals.**—Birds are more important than any other animals except man as distributors of seeds. The seeds of many small, fleshy fruits pass through the intestines of birds undigested. Since birds fly great distances the seeds are rapidly and efficiently distributed. The seeds of hawthorne, juniper, raspberry, blackberry, strawberry, wild grape, sumach, elder, and goose-

berry are known to be distributed in this way (Fig. 128). This accounts for the relative abundance of these plants along telephone lines, fences, and under dead trees where birds have roosted.

Fruits which have pits or seeds too large to be swallowed may be carried some distance from the parent plant and eaten, and the seeds dropped on the ground. The author once counted 109 cherry stones within a space of one square yard along a fence which was about one hundred yards from a group of wild cherry trees.



FIG. 129.—The hooked fruits of the burr marigold, *Bidens*. They remain on the plant all winter unless they are carried away by some passerby.

Small seeds are often mixed with the mud on the feet of birds and other animals. Darwin germinated eighty-two seeds from the mud taken from the feet of a partridge. Seeds are not only carried in considerable numbers in this way, but may be well planted in the footprints of the animal carrying them.

Many fruits and seeds are provided with hooks which catch in the fur of animals or the clothing of people. The cocklebur and burdock fruits often remain in the manes and tails of horses, the tails of cattle, and the wool of sheep for a very long time. More than ten species of the bur marigold (*Bidens*) are famous for their clinging qualities, and are known as beggar-ticks, stick-tights, Spanish needles, and tick

seeds. The loment of the legume family were mentioned in the previous study. The stick seeds and hooked nutlets of the various species of the borage family are also well known. (See Figs. 118, 119 and 129.)

*The distribution of nuts* is somewhat difficult to understand. They are large seeded, hence much energy goes into their making. They are all eaten by animals and some by birds. Nearly every nut has various beetle larvæ which live in it and eat it. Woodpeckers store nuts and acorns, and eat the grubs out later. Blue jays and squirrels store away and eat great numbers of nuts.

It must be evident that with this host of enemies a nut has small chance of surviving, but the trees live many years, and if each tree, during its life, establishes another to take its place when it dies, the race will persist. Some of the nuts which are hidden away are not found again by the animal which hid them, and some of them are in situations favorable for growth. Some of them are dropped, for various reasons, while being carried. Squirrels have a strong habit of burying nuts in the ground in the fall of the year. This serves to plant them.

Squirrels bury many nuts in excess of what they recover and eat. It is believed that no squirrel can possibly live to eat nuts from the tree that may grow from a nut of his planting. In the economy of nature, not only the individual is considered, but the race as well. If the offspring of the squirrel which buried the nut, even in the fifth or tenth generation, eats nuts from the tree, the race has been benefited. Thus nut trees and squirrels coöperate for their mutual benefit.

**V. Distribution by man** is coming to be the greatest of all methods of seed distribution. If we think of the fields of grain, orchards, gardens, and shade trees, we realize that man is no small agency in the distribution of plant life. At the will of man, forests and prairies are converted into farms. In some places, swamps have been drained, or deserts irrigated, to provide for more plant growth.

Not only has man planted valuable crops, but he has distributed weeds and plant diseases as well. Many of our worst weeds are foreigners, having been brought in with our diverse trade and commerce. We have mentioned how new kinds of plants and

animals were brought to Australia by man. In time to come, it is probable that every plant and animal will be brought to all places where it can live and maintain itself.

### OUTLINE-SUMMARY

Distribution of seeds is the method by which plants establish themselves in new situations or reestablish themselves in places where they have been eliminated.

Elastic mechanisms: cranesbill, touch-me-not, butter and eggs, evening primroses, mullein, jimson-weed, witch hazel, sand-box tree, squirting cucumber, pansy, violet, Jersey tea, wild balsam, herb Robert.

Wind distribution: ash, elm, maple, catalpa, pine, trumpet creeper, thistle, dandelion, lettuce, cotton-wood, milkweeds, tickle grass, squirrel-tail grass, tumbleweeds, peppergrass.

Water distribution: cocoanut, water lily.

Distribution by animals: birds, hawthorne, juniper, raspberry, blackberry, strawberry, wild grape, sumach, elder, gooseberry, cherry. Other means; burs, nuts.

Distribution by man: grain, orchards, gardens, weeds, plant diseases.

**Review Questions.**—Why is it necessary for plants and animals to distribute themselves? Why were the plants and animals of the other continents not found in Australia until after Europeans began to live there? Mention some plants which distribute their seeds by elastic mechanisms. Describe the mechanism and its operation in each case. Name some winged seeds and fruits and describe how they are distributed. How are cocoanuts distributed? How are the seeds of the yellow water lily distributed? In what ways may birds distribute seeds? How may animals with fur distribute seeds? How may nuts be distributed? How does man distribute seeds?

### SUGGESTED SPECIAL ACTIVITIES

**Laboratory Work.**—Let various seeds fall from a point near the ceiling and note which fall the fastest. If a wind is blowing which will be carried the farther-



est? Note how beautifully the seeds of the maples and pines spin. Draw some of them.

**Field Collections.**—Collect as many seeds as possible and classify them according to their methods of distribution. Save them.

### References

Stevens, *Introduction to Botany*, D. C. Heath & Co.

Jenkins, *Interesting Neighbors*, P. Blakiston's Son & Co.

Beal, *Seed Dispersal*, Ginn & Co.

### PROBLEM 10. HOW DO SEEDS GERMINATE AND BECOME SEEDLINGS?

**General Questions.**—Are all seeds similar in the number and arrangement of their parts? Of what parts are seeds composed? Of what parts are seedlings composed? What is the work of each part of a seedling? Do all seeds emerge from the soil in the same manner? Do all seeds contain endosperm? What is its use to the seedling?

We have seen how seeds are formed and how they are related to the spores of ferns and mosses. We have said that seeds have an advantage over spores in that they have a supply of food within themselves for the nourishment of the young plant. Seeds are not all alike. In this study we shall try to answer the problem of how seeds germinate by presenting four typical seeds and their seedlings. Seeds of the flowering plants are of two types—those which have one cotyledon, and those which have two. The seeds of grasses, grains, and lilies are common examples of seeds which have only one cotyledon. They are the seeds of monocotyledonous plants. We shall study the grain of corn as an example of this type. The plants which have two cotyledons in their seeds will be represented by the seeds of the bean, pea, and squash each of which has some special characteristics not possessed by the others.

**A grain of corn** is a good representative of the monocotyledonous type of seed. It is covered by a tough coat which is the remains of the ovary in which it grew. It is an entire fruit. The greater part of the seed is filled with starch which occupies the broad end of the kernel, and is the endosperm formed by a secondary growth within

the embryo sac as described in a previous study. (See Figs. 130 and 131.)

A groove is formed along one side of the grain. It is the region in which the embryo is situated. When the seed is soaked in water the embryo enlarges, and the groove swells and becomes a ridge. The young shoot grows out of the end of the ridge toward the broad end of the kernel, and the primary root grows out of the end toward the point of the kernel. Usually two other roots soon appear, and

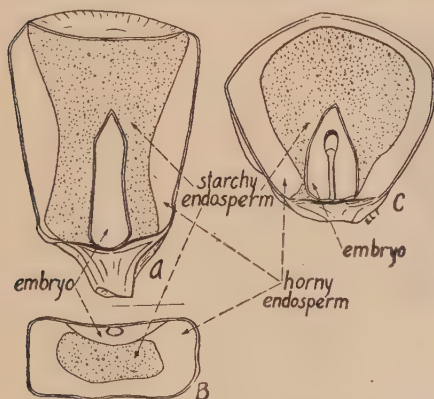


FIG. 130.

FIG. 130.—Sections of corn grains. A, Dent corn; C, flint corn, both length-wise sections. B, Cross section of dent corn. (Robbins.)

FIG. 131.—A longitudinal section through a germinating grain of corn. F, fibrovascular tissue through which the sap passes from the scutellum to the embryo. The scutellum is considered to be the cotyledon, but there is some disagreement in regard to this point among authorities.

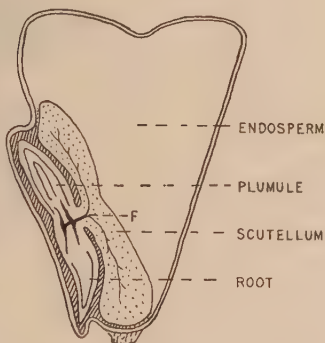


FIG. 131.

grow in the opposite direction along the surface of the grain. These roots then grow out and branch extensively in establishing the root system of the young plant. The first structure to grow out of the corn grain where the shoot is developing is the *plumule sheath* within which the *plumule* makes its appearance. The plumule is the seed-bud which is to develop into the first leaves and young stem of the plant. (See Fig. 133.)

The *cotyledon* (seed leaf) of the corn grain is single, and does not rise above the ground when the grain germinates. The *scutellum* is an extension on the side of the embryo which absorbs food for the

growing plant from the endosperm. It secretes an enzyme which changes the starch of the endosperm to a sugar. Starch being insoluble can not be taken up. Glucose is soluble, and is transported through the fibrovascular tissue of the young plant.

**The bean seed** (Fig. 132) is a favorite with students in elementary botany as an example of a dicotyledonous seed. The embryo is very large occupying nearly all of the interior of the seed. The endosperm is practically all absorbed by the embryo before the seed is ripe,

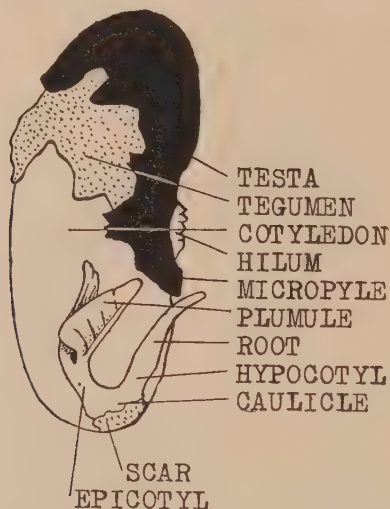


FIG. 132.—A soaked black wax bean seed with the seed coats partly removed and one cotyledon removed. The scar where it was broken off is shown.

and, hence, it does not appear in the ripe seed. The food taken up by the embryo is mostly stored in the cotyledons.

The *testa* and *tegumen* are the outer and inner seed coats respectively. They are the remains of the ovule in which the embryo grew.

The *hilum* is the scar on the concave side of the seed, and marks the place where it was attached to the inside of the pod.

The *micropyle* is a small opening on one side of the hilum, and is the place where the pollen tube entered the ovule in fertilizing the egg which developed into the seed.

The *embryo* occupies the interior of the seed, and is composed of the following parts:

The *two cotyledons* are the two halves of the bean. They are the first leaves of the seedling, but in the bean they do not look much like leaves. Between them, at one end, lie the parts that are to become the root and shoot of the young plant.



FIG. 133.

FIG. 133.—Three seedlings,—corn on the left; pea in the center; and bean on the right. Note that the endosperm of the corn and the cotyledons of the pea stay in the soil, but that the cotyledons of the bean are lifted up into the air.

FIG. 134.—Drawing of a squash seedling to illustrate the parts of a typical seedling. At this stage of development the upper part of the caulicle is known as the *epicotyl*, and the lower part as the *hypocotyl*.

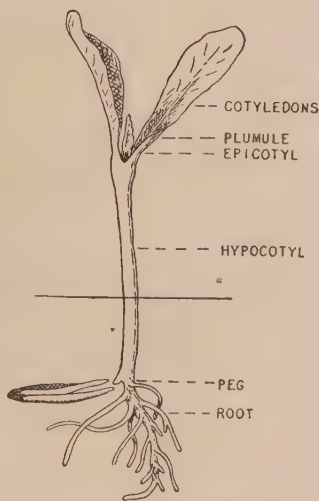


FIG. 134.

The *plumule* is the pair of little leaves which are attached to the cotyledons by a short stem called the *epicotyl*.

The *hypocotyl* is the continuation of this stem below the cotyledons. The portion next to the cotyledons is called the *caulicle* and the tip is called the *radicle* or *root*. These terms should be memorized in connection with the illustrations.

**The pea seed** (Fig. 133) is similar to the bean, but when it sprouts the cotyledons remain in the ground. As a result of this the hypocotyl is very short and the epicotyl grows very fast to bring the leaves of the plumule to the surface of the ground as soon as possible.

**The squash seedling** (Fig. 134) is interesting because of the development of a process called the *peg* on the side of the caulicle. It is used to push off the seed coats. Consult the illustrations and understand how it is done (Fig. 135).



FIG. 135.—Five stages in the development of a squash seedling. Note how the peg pushes off the seed coats.

In the squash seedling the cotyledons are green, and manufacture starch. They also serve as a storehouse for food in the seed. In the bean the cotyledons rise above the ground, but do little or no photosynthetic work. In the pea the cotyledons serve entirely as a place of storage for food, not even emerging from the ground when germination takes place. In many seeds, such as the castor bean seed, the food is in the endosperm when the seed is mature; the embryo not having absorbed it before the seed ripened. These seeds have thin cotyledons which are admirably adapted for photosynthesis, respiration, and transpiration. The removal of the food matter from the



endosperm, and its storage in the cotyledons is a specialization possessed by the higher groups of the dicotyledons. It makes the food more readily available when it is needed in germination. The loss of the cotyledons for photosynthetic work is compensated for by a very rapid appearance of the first pair of plumule leaves.

### SUMMARY

Seeds of flowering plants have one or two cotyledons. Corn is a monocotyledon because it has but one. Peas, beans, and squashes are dicotyledons because they have two seed leaves.

Corn has much endosperm in the seed and the embryo has developed a special structure with which to absorb it. The seed remains in the ground when it germinates.

The pea seed has two large rounded cotyledons which do not emerge from the soil when the seed germinates.

The bean lifts its cotyledons into the light but they are of little value as green leaves.

The squash lifts its cotyledons into the light and uses them in making food.

**Review Questions.**—Why are some seeds said to be monocotyledonous and others dicotyledonous? Describe the corn seed; the bean; the pea; the squash. Make a sketch of each of the four seedlings about which we studied in this lesson and label all parts? Compare each seed as to endosperm, cotyledons, and method of emerging from the soil.

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Suggestions.**—Appoint committees to plant seeds of the bean, pea, corn, and squash or pumpkin. Study and draw these specimens in the laboratory. **Precautions.**—Make more than one planting, plant in sand or sawdust, keep away from mice, keep warm, and do not fail to water them. Start them two weeks before they are needed.

### References

- Eikenberry, *Problems in Botany*, Ginn & Co.  
Osterhout, *Experiments With Plants*, Macmillan Co.  
Payne, *Experimental Botany*, American Book Co.  
Atwood, *Problems, Projects, and Experiments in Biology*, P. Blakiston's Son & Co.  
Bergen and Caldwell, *Practical Botany*, Ginn & Co.  
Stevens, *Introduction to Botany*, D. C. Heath & Co.

PROBLEM 11. WHAT CONDITIONS OF THE ENVIRONMENT CONTROL  
THE GROWTH OF SEEDLINGS?

**General Questions.**—Do seeds need water for germination? How is temperature related to the growth of seedlings? How do seedlings use air? Will seeds germinate without it? Will seeds germinate in absence of light? Is it of value to seedlings? Do seedlings need food for their early growth? How does gravity influence the roots and stems of seedlings? How does light influence the growth of seedlings?

It is a well known fact that seeds which are kept in the package do not grow, and those which are planted in the garden usually do; but just what the conditions determining germination are is not easily understood. It is a matter of great importance with us whether our seeds germinate well or poorly in spring. It sometimes happens that entire fields must be replanted because some of the necessary conditions for the good growth of seedlings were not right. Perhaps you have heard of people planting crops when the moon is in a certain phase, or when a certain date has been reached on the calendar. It is the business of science to know just what causes seeds to germinate, and under just what conditions seedlings will thrive the best. If these facts are known, we will pay no attention whatever to the moon and very little to the calendar, but will wait with our spring planting until certain factors are favorable and then plant. The main factors of germination are *water, temperature, air, light, and food.*

**Water.**—Many seeds must attain a certain age and be dried before they will germinate properly. On the other hand, if some seeds are thoroughly dried they will not grow. Seeds which are produced in the spring—as are those of the elm and maple, germinate at once; and can not withstand much drying.

Water enters the seed by soaking through the seed coats. Some water may enter through the micropyle, but this means of entrance has been over-worked in botany classes. The water is taken up by the embryo by osmosis, and growth is stimulated if other conditions are favorable; if they are not, bacterial action may set in, and the seed will decay.

**Temperature** is the factor in the temperate zone which prevents seeds from germinating in winter or at an improper time in the spring or autumn. Chemical activity of most kinds is increased by a rise in temperature. Some seeds will germinate at much lower temperatures than others. A temperature only a little above freezing is sufficient to start germination in peas. Each kind of seed has its *minimum temperature* of germination below which it will not sprout, its *optimum temperature* at which it germinates best, and its *maximum temperature* above which it will not grow. Many crop

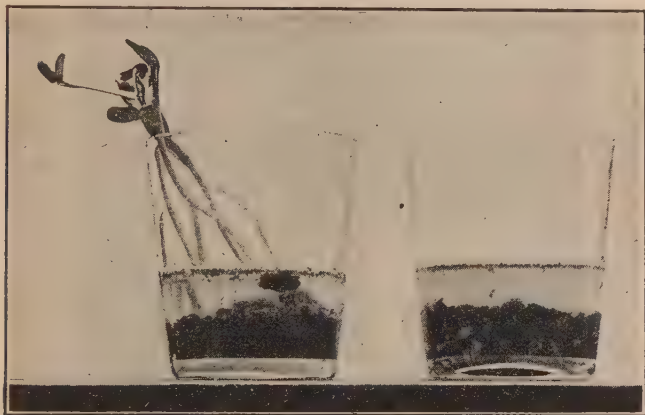


FIG. 136.—Sunflower seeds will sometimes germinate in soil which is under water but pea seeds will decay. Try this experiment. Which of the five germination factors is lacking under water? Why did the pea seeds fail to grow?

failures are due to the fact that seeds are planted before the soil is warm enough to start a rapid germination. If in doubt the temperature of the soil should be tested with a thermometer. Some of the most successful farmers, do not guess, but always know that their soil is warm enough to support germination before they plant.

**Air** is necessary for the germination of all seeds, but is used in greater quantity by some than by others. The oxygen of the air is taken up by the embryo and used in oxidizing the food material within it. This oxidation produces carbon dioxide and water and is a form of respiration. It releases *heat* which is used to maintain

the seed at a temperature higher than that of the soil in which it is, and thus hasten its germination.

If air is excluded bacterial action may set in, and the seed will decay. Too much water stops or retards germination because it excludes air, but some seeds get enough air from water to germinate (Fig. 136). The seeds of most any water plant will serve as an example.



FIG. 137.—Squash seedlings grown in the dark. Try to determine in the laboratory how long various seedlings are able to live without light. How do these seedlings differ from those which are grown in light?

*Carbon dioxide* from the air is of no value to the seedling until green tissue appears and the parts which are to do photosynthetic work are brought into the sunlight; then it is essential to the rapid growth of the young plant, for photosynthesis is about twelve times as extensive in plants as is oxidation. Review the study on leaves.

**Light** (Figs. 137 and 140) is of little consequence until after the green parts appear. If it is not available then, no green tissue will form; no starch will be made; the plant will remain pale yellow in

color, and become long and slender. None of the seedlings of the green plants can live long without light, but some require much less than others. If a seedling which has been kept in darkness is suddenly brought into strong, warm sunlight the tissues will be killed by the action of the light; due to the fact that no chlorophyll has been formed to absorb the rays and thus protect the sensitive protoplasm. The seedlings of clover, alfalfa, and many trees require some shade while they are young for their best growth.

**Food** enough for germination is stored in some part of the seed, but as soon as the root hairs form on the young root mineral food should be available for the best growth of the seedling. The seedlings which grow from large seeds, as a rule, develop faster than those that grow from small seeds. Why? (See Fig. 138.)

**Tropisms** are the movements of plants, in response to some outside force. It is well known that roots grow toward the center of the earth, and that leaves grow in the opposite direction. It is interesting to note that if a seedling is whirled rapidly while it develops, centrifugal force will overcome gravitation, and the roots will all grow outward from the center of rotation while the shoots grow inward. This experiment was first performed by Thomas Andrew Knight, an English botanist. It shows that the response is not conscious in any way, but is purely automatic. This tendency of plants to respond to gravitation is known as *geotropism* (Gr. *ge* = earth + *trope* = a turning). Roots are said to be *positively geotropic*, and shoots are said to be *negatively geotropic* (See Fig. 139).



FIG. 138.—Two pea seedlings to show the value of the food stored in the cotyledons. They were removed from the seedling on the right, and were left on the one on the left. They germinated at the same time.



*Roots grow toward water.* This is partly due to the fact that the ones coming into a moist region will be better fed, and hence will grow more abundantly than those not so well favored. Too much

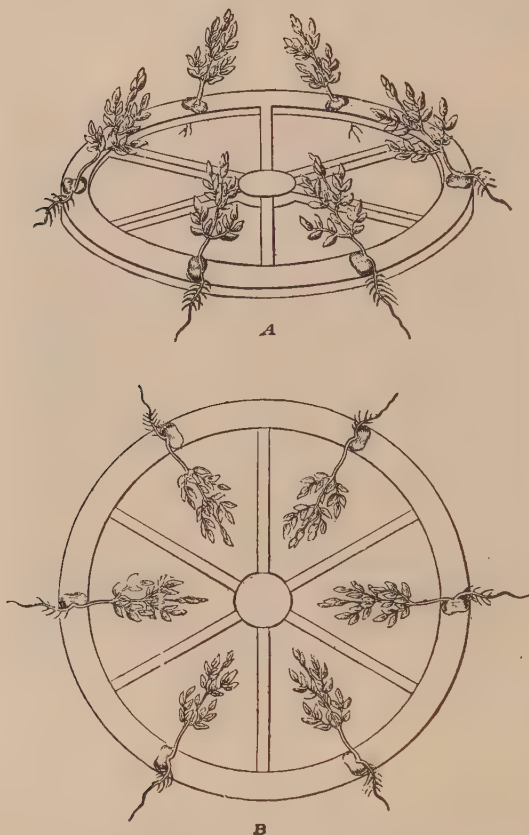


FIG. 139.—Knight's experiment to show that centrifugal force causes the same response as gravity in seedlings. The seeds were fastened to the wheel which was kept rotating in a moist atmosphere while the seeds germinated. (Gager, after Knight.)

water retards their growth. If the subsoil is too wet, most of the root growth will be near the surface. Then if drouth occurs the crop will be withered. Why? The tendency of plants to respond

to the influence of water is called *hydrotropism* (Gr. *hydro* = water + *tropé*).

We have seen before that the leaves of plants respond to light influences. This is known as *phototropism* (Gr. *photos* = light + *tropé*). The leaves of seedlings are especially sensitive to light, and grow toward it. Experiments have been performed to show that roots shun light, but this negative reaction is not so marked as is the positive reaction of the young stem and leaves. (See Fig. 140.)

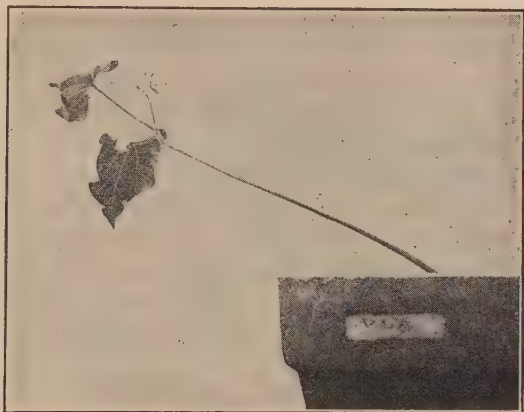


FIG. 140.—Phototropism experiment with a bean seedling. The light comes from the left.

An examination of a bit of soil where weed seedlings are growing in the spring will convince the student that many more seeds sprout than can possibly produce mature plants. Tropisms are large factors in determining which shall live and which shall be crowded out of existence. Those that obtain the best mineral food for their roots and the best light and air for their leaves will have the best chance of survival.

#### OUTLINE-SUMMARY

Water is obtained by osmosis by seedlings and is necessary for their germination.

Temperature must be right or seeds will not grow. If it is just right it is optimum; if too cold it is lower than the minimum; if too hot it is above the maximum.

Air furnishes oxygen for the release of energy in respiration, and when the seed germinates carbon dioxide is furnished to the leaves of the seedling.

Light is not necessary for germination, but is necessary for the processes of food-making in the seedling.

Seedlings are supplied with food from the endosperm or cotyledons until they can make their own food.

Tropisms: responses to gravitation, water, light.

**Review Questions.**—How do seeds use water in germinating? What may happen if there is too much water? Do all seeds germinate at the same temperature? What is meant by minimum and maximum temperature of germination? In what two ways do seedlings use air? Is light essential to germination? Is it of importance to seedlings? How? What may be the advantage of a large amount of food stored in a seed? How do seedlings behave in reference to gravitation? How did Knight show that the plant is not conscious of what it does? How do roots respond to water? How does the presence or absence of light affect seedlings?

### SPECIAL STUDENT ACTIVITIES

**Laboratory Suggestions.**—The following may be assigned to students as problems to be worked out in groups of two or more.

Will seeds germinate without water? At a low temperature? In the dark? In water? Without soil? Does soaking seeds before they are planted cause them to come up more quickly? How long must squash seeds be removed from the squash and dried before they will grow? Plant some pea seeds in a sealed bottle. Do seeds require air for germination? Fill a small flower pot with corn grains and fasten the saucer over the top with wire. Make it tight. Keep it moist for a few days. Why must germinating seeds exert force?

Appoint committees to illustrate geotropism, hydrotropism, and phototropism. All of this work should be started some time before this study is taken up in class.

Compare the size of seedlings grown from large and small seeds. Which have the best chance to live? Cut the cotyledons from some bean and pea seedlings and compare them with others which have been allowed to retain theirs at the end of a week. How important is the food stored in seeds?

## References

- Atwood, *Problems, Projects, and Experiments in Biology*, P. Blakiston's Son & Co.  
Osterhout, *Experiments with Plants*, Macmillan Co.  
Payne, *Experimental Botany*, American Book Co.  
Eikenberry, *Problems in Botany*, Ginn & Co.

## STUDY 12. SOME SPECIAL METHODS OF PLANT REPRODUCTION

**General Questions.**—What are the relative advantages of seeds and spores as agents of reproduction of plants? How may plants be propagated by roots? What special adaptations have plants made of their stems for propagation? Why do we transplant young plants? Why do we graft fruit trees? Are plants ever propagated by their leaves?

**Propagation by Spores and Seeds.**—We have seen how the algæ, mosses, and ferns propagate (multiply) themselves by spores. These spores are produced in great numbers. They have the disadvantage, however, that they contain little reserve food matter, and must secure food immediately after germinating or they can not live. Seeds are produced in smaller number, but they are surer of germinating successfully, because of the reserve food which they carry. They often have the additional advantage of possessing some special means of distribution.

In this study we are interested in the methods by which plants are multiplied without involving seeds or spores. These methods are frequently spoken of as *vegetative reproduction*. Man has developed some of the special ways of propagating plants to a fine art, and we would not have many of our best fruits and vegetables if we tried to raise them all from seed. Animals can not be multiplied by any of these special methods, and this is one of the reasons why we do not, as a rule, have so many varieties of domestic animals as we do of plants. The new varieties are lost in subsequent breeding; but if we get a new kind of fruit, we can keep it by grafting, even if it can not reproduce itself from seeds.

**Propagation by Roots.**—*Root sprouts* are shoots which spring up around the parent plant from its roots. Cottonwoods, plums, and lilacs are famous for this. If the tree has not been grafted these sprouts will be of the same variety as the parent, and may be taken

up and planted. Sprouts in an orchard are not wanted, however, and trees should be bred from which sprouts do not grow. Blackberries and red raspberries are commonly propagated in this manner (Fig. 141).



FIG. 141.—Root sprouts of the wild raspberry. The patch maintains itself by sending up sprouts from the roots each spring. The shoot grows the first summer, bears fruit the second, and dies down to the ground in the fall. Raspberries are propagated artificially by transplanting these shoots.

*Fleshy roots* (Fig. 142) of the dahlia, sweet potato, and asparagus grow about the base of the plant in clusters. They are taken up, separated, and planted. Each root makes one or more plants. In the sweet potato this practice has taken the place of the ability of the plant to produce seed, and all propagation is by this method.



**Propagation by Stems.**—*Rootstocks* are the thickened, underground stems possessed by ferns, cat-tails, blue flags, and many grasses, such as Johnson grass and Bermuda grass (Fig. 45). In their underground position rootstocks are protected from mechanical injury, frost, and grazing animals. The Canada thistle owes its reputation as a weed which is difficult to eradicate, to its rootstocks.

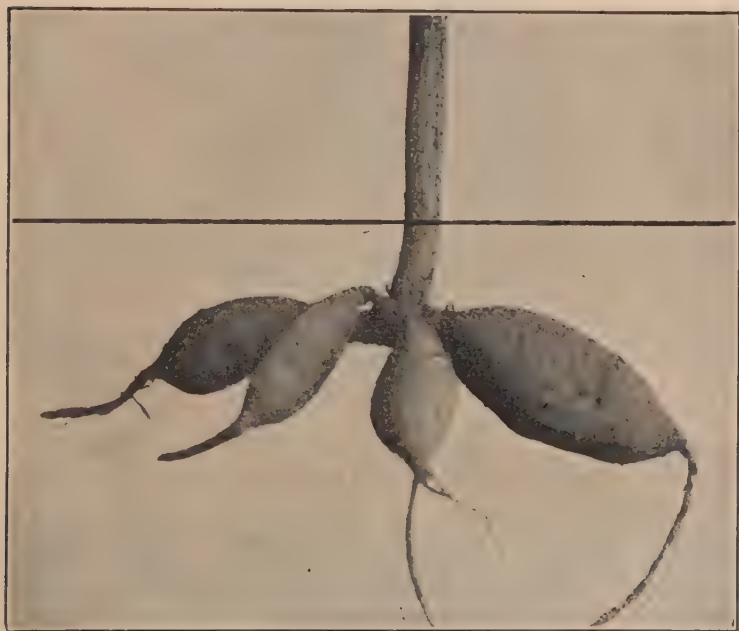


FIG. 142.—Fleshy roots of the dahlia. Each root will make a plant the next season if they are separated and planted.

*Tubers* are possessed by the potato and the artichoke. The tuber is an enlargement at the end of a rootstock. The common forms of the potato no longer produce seed. When seeds are secured and planted, the resulting plants are exceedingly variable. New types may be established by selecting favorable variants. The new type must be propagated by planting the tubers, otherwise the type will be lost. (See Figs. 46 and 143.)

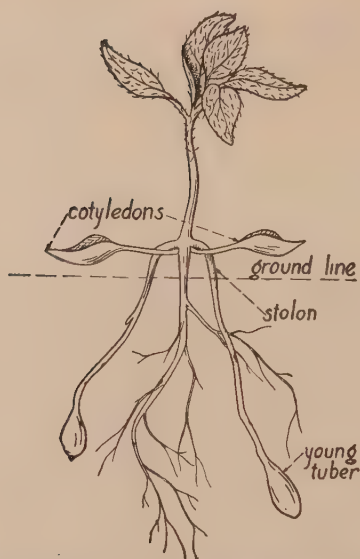


FIG. 143.—A seedling potato. To show that tubers grow from the stem of the plant, and are not roots. Note the long stolon on which the tuber grows. (*Robbins.*)

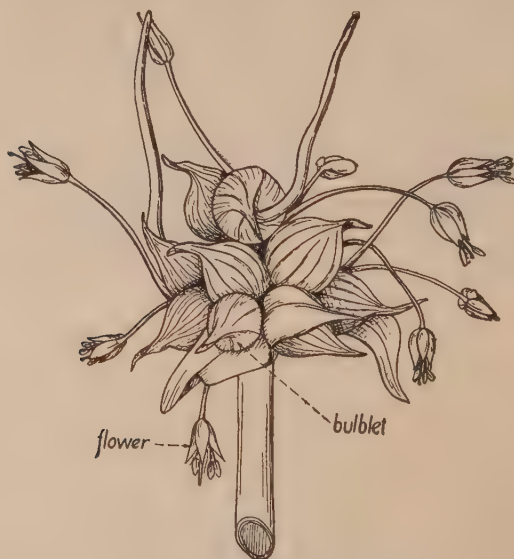


FIG. 144.—Top onions. These are bulbets or onion sets. Note the flowers growing among them. (*Robbins.*)



FIG. 145.—The corm of the cyclamen. This plant may be raised from seed and is a very beautiful flowering plant. Secure one for the laboratory.



FIG. 146.—Strawberry plant with a stolon which has started a new plant.

*Bulbs* are fleshy buds formed under ground, and are the means of propagating many domestic plants. Lilies often bear buds in the axils of their leaves which are small bulbs, and will grow if an opportunity is given them. These aerial buds are called *bulblets*, or as in the case of the onion, *sets*. Some onions and many domestic lilies have lost the ability to produce any seed at all (Fig. 144).



FIG. 147. A rooted cutting of the geranium. The geranium is one of the easiest of all plants to raise from cuttings.

*Corms* (Fig. 145) resemble bulbs, but are more solid, being composed of a fleshy, hard stem-base, surrounded by dry scales. They are found in the gladiolus, caladium, and Jack-in-the-pulpit. The gladiolus produces many small corms, called *cormels*, around the parent each season. They may in time be able to produce flowers. Both bulbs and corms multiply during the summer, each parent

yielding from two to four large specimens which may be planted again the next season. Increase by bulbs and corms is comparatively slow, but sure.

*Stolons* are slender branches which run out from the parent plant, and take root near by, thus establishing another plant. The



FIG. 148.—A well rooted strawberry plant ready to be transplanted. This is the most common method of propagating strawberries. (*Farmers' Bulletin* No. 198.)



FIG. 149.—Method of making a whip graft. *a*, the stock; *b*, the scion; *c*, the two united. In this case the stock is a root. (*Farmers' Bulletin* No. 157.)

strawberry (Fig. 146), a primrose, and the Boston fern are examples of plants which send out very slender stolons called *runners*.

*Layering* is resorted to in multiplying many kinds of vines, especially grape vines and roses. The slender stem is bent over and buried until it takes root. It is then cut off and set out.



The canes of the black raspberry do not run along the ground as do the runners of the strawberry, but the tips of the canes touch the ground and take root. This is a case of natural layering.

*Cuttings* (Fig. 147) are made from plants which root easily. Willows, elms, and poplars are well known examples among the trees. When house plants are propagated in this way the cuttings are called *slips*. This is almost exclusively an artificial method, but in nature

the twigs of the crack willow often take root when broken off by the wind. Sugar cane is propagated entirely by cuttings. The canes of the year before are cut in pieces and buried in trenches. They take root and produce the next crop.

*Transplanting* is another artificial method of propagating many plants—such as cabbage, tomatoes, peppers, and most all trees, vines, and shrubs. It is resorted to to conserve work and space and to get an earlier start for the plant. (See Fig. 148.)



FIG. 150.—Photograph of a shoot growing from the tip of a leaf of the live-for-ever.

*Grafting* (Fig. 149) is resorted to by nurserymen because fruit trees do not breed true from seed. A *scion* is a portion cut from a tree of the desired variety, and is to be grown on a root or stem of another plant called the *stock*. The scion and the stock must be closely related or the graft will not be successful. Apples and pears, or almonds and peaches, or pecans and hickories can be grafted together; but an apple and a

hickory can not be successfully united in a graft. Of course all kinds of apples will grow on all other kinds of the same fruit, but some varieties are more adapted to grafting than others.

In a graft the scion determines the kind of fruit. The stock contributes the root system. The *whip graft* is most often used to unite scions to roots. The *cleft graft* is used in top grafting—*i.e.*, cutting back the top of a tree, and by grafting causing it to bear a different variety of fruit. *Budding* consists in inserting a bud,

representing a scion, under the bark of the stock. It is very popular with nurserymen.

**Propagation by leaves** is of little consequence. The walking fern, some begonias, and live-for-ever are propagated in this way, and resort to this unusual process in nature (Fig. 150).

**The fundamental purpose of plant propagation** is the multiplication of the number of individuals, but since many domestic plants tend to revert to their former condition when raised from seed, the increase must be secured without permitting the quality of the stock to decrease. Many domestic plants are seedless or do not breed true from seed. These must be propagated by some other means. The true plant propagator should also be a plant breeder—*i.e.*, he should improve the quality of the plants which he grows from year to year; but we will have more to say about this in another study.

#### OUTLINE-SUMMARY

The general method of propagation is by spores or seeds. Other methods are called vegetative reproduction. They are of special value in the growing of domesticated plants.

Propagation by roots; root sprouts, fleshy roots.

Propagation by stems; rootstocks, tubers, bulbs, corms, bulblets, cormels, stolens, runners, layering, cuttings, slips.

Transplanting is an economical method of raising vegetables and trees.

Grafting is resorted to in order to preserve a type of fruit which will not breed true from seed. Stock, scion, whip graft, cleft graft, budding.

Propagation from leaves occurs in begonias, live-for-ever, and the walking fern.

**Review Questions.**—What plants propagate by spores? What by seeds? What is meant by “vegetative reproduction”? Name some plants which propagate by their roots, and tell how they do it? Tell how some plant propagates by each of the following methods: rootstocks, tubers, bulbs, bulblets, sets, corms, cormels, stolons. How are plants propagated by layering? By cuttings? By transplanting? Why are trees grafted?

Describe three kinds of grafts. Can dissimilar trees be grafted together?

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Projects.**—Divide the class into committees. Let each committee demonstrate a method of plant propagation, and report to the class when the specimens are ready. It may not be possible to have them all alive and growing. If some are started early in the course, they may be in an advanced stage of growth when this study is reached.

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### STUDY 13. THE REPRODUCTION OF ANIMALS

**General Questions.**—Is there an alternation of generations in the life cycle of animals? Is the reproduction of frogs and toads typical of animals? When are their eggs produced? When and where are they laid? How does a toad's egg develop? How does the young toad breathe? What do tadpoles eat? How does the development of some other animals compare with that of toads and frogs?

We have seen that the life histories of plants are complicated because of the alternation of spore producing with gamete producing generations in mosses and ferns, and the addition of seed production by the higher plants. Perhaps we should consider it fortunate that we have no such complicated processes to study, if we wish to gain a general knowledge of the development of an animal.

Animals do not produce spores, nor do they have any such an alternation of generations as do plants. However, we do find some very complicated processes of both internal and external budding among some of the worms and jellyfishes which practically amount to an alternation of a sexual with an asexual generation; but we will not try to explain this process.

Perhaps we can get at the subject in the best manner, if we choose a type of reproduction which is fairly representative of all animals, and study that with some degree of detail. Frogs, toads, and salamanders are found nearly everywhere in abundance. Their eggs are easily obtained. We are all more or less familiar with their tadpoles, and their development is representative of animals. Therefore, we shall study the development of the eggs of frogs, toads, and salamanders.



FIG. 151.—Salamanders (*necturus*) with their eggs fastened to a rock under water. This salamander never loses its gills, and lives in the water like a tadpole all of its life. Salamanders keep their tails when they are fully grown, even if they live on land. (*Pearse, U. S. Bureau of Fisheries.*)

If you ever have caught a frog or toad in the fall, you have probably been impressed with the fact that it was very fat. They eat heartily all summer so that they may have enough fat to keep them in good physical condition all winter. Toads live in the ground and frogs live in the water all through the long winter.

Their fat is not only used to produce energy for their welfare, but much of it is used in the formation of eggs by the females and

sperms by the males. All through the winter the eggs are developing, and drawing extensively on the food supply which was obtained the summer before.

The surest sign of spring is the loud and persistent singing of many kinds of frogs and toads. Whether we enjoy it or not, it seems to be very attractive to them. It is their way of calling their mates to the places in the ponds where they are. There are several kinds of frogs and toads in nearly every community. Each kind has its own type of song, if we may call it that; and they each have their own time for egg laying.



FIG. 152.—The bullfrog. This is our largest frog. It lays its eggs comparatively late in spring. (*Wright, U. S. Bureau of Fisheries.*)

**The female frog** lays her eggs in several large masses which are more or less entangled with the vegetation of the pond; but the female toad lays her eggs in long strings which look like strings of beads in a string of jelly. The “jelly” which surrounds the eggs is very much like the white of a hen’s egg, and is increased in bulk by absorption of water after the egg is laid.

**The male** deposits sperms over the eggs as the female lays them. The sperms swim around in the water, just as do the sperms of plants. When one comes to an egg, it penetrates the “jelly” which surrounds it, and then penetrates the egg itself. Each egg and each sperm



has a nucleus, for both eggs and sperms are typical cells and have all of the parts of a cell. The two nuclei—one from the sperm and the one of the egg—unite together to form the *nucleus of the fertilized egg*. When the two nuclei have united, the egg is said to be *fertilized* and is ready to begin its development.

The so called *yolk* of the egg is the egg itself and is not yellow as in birds and reptiles, but is black on its upper surface and white below. The black side remains uppermost at all times, because it is lighter in weight than the white side. The black side is called the *animal pole* of the egg, and the white side is called the *vegetative pole*. The vegetative pole contains a relatively large amount of food which is to be used by the growing tadpole before it is able to eat.

The egg begins its development by a cell division in a vertical plane which cuts the egg into two equal parts. The second division is also vertical but at right angles to the first. The third is horizontal and at right angles to both of the first divisions, but it is not equidistant from the two poles. It is a little nearer the top than the bottom. From this time on the divisions of the cells of the egg

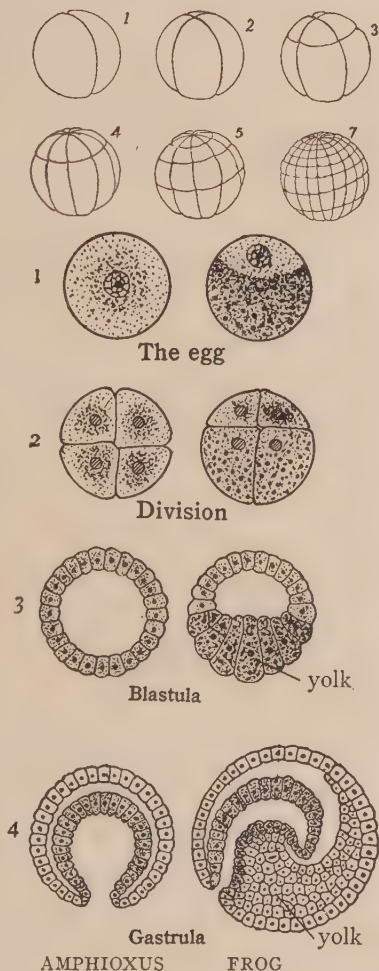


FIG. 153.—Early stages of the development of the egg of the frog and amphioxus to show unequal division of the cells, the formation of the blastula and gastrula, and how the frog's egg is modified by the presence of yolk cells. (Modified from Galloway.)

are unequal and irregular, the cells of the upper half being smaller than the white ones below. As cell division continues a hollow ball is formed, but the lower wall composed of the white cells is much the thicker. This stage is called the *blastula* (little ball). The blastula stage is followed by the *gastrula* (little stomach) stage in which the beginning of the alimentary canal is formed; but the formation of this stage is not easily described for the frog, as it is complicated by the presence of the large yolk cells.

The formation of the gastrula is represented in a very perfect way by amphioxus, a simple animal type which lays eggs which have no yolk. In this form the gastrula stage develops from the blastula very much the same as a hollow rubber ball might be pushed in on one side by forcing the thumb against it until it nearly touches the opposite side. This cavity which surrounds the thumb represents the primitive stomach or gastrula. (See Fig. 153.)

**Tadpoles** are the young of frogs and toads. When they emerge from the "jelly" which surrounds the egg (Fig. 154), they fasten themselves to objects in the water by means of suckers which appear near where the mouth is to be. When the mouth is formed, it is very small and is suited to eat algæ and other minute life of the ponds. The tadpole is a vegetarian, and not a meat eater as are the frogs and toads.

Respiration is carried on by means of *external gills* which may be seen on the sides of the head like little plumes. These soon disappear and *internal gills*, just like those of fishes, are developed in their place. At this time the tadpole is a typical fish with a long tail for swimming and a blood system, muscle system, and nervous system like that of fishes. Eventually lungs develop in the chest cavity of the body, and the tadpole comes to the surface to breathe at increasingly frequent intervals. When it leaves the water the gills have given place to the lungs entirely.

When the tadpole has become quite large, you may see a pair of hind legs near the junction of the body and the tail. There are front legs at this time also, but they are extended in the gill-chamber and can not be seen from the outside. When the front legs appear, the tail begins to be absorbed, the mouth and eyes become larger, and the tadpole ceases to eat.



FIG. 154. — Development of the toad tadpole. Note the strand of eggs, the three young holding on by their suckers, the one with external gills, and the appearance of the hind legs before the front ones appear. (*Jenkins.*)

When the tail is completely absorbed, on a moist day, perhaps a rainy day, the toads come out of the water to begin their life on land. Toads leave the water in July, but the common leopard frog seldom finishes its tadpole life before August in the northern states. Of course the farther south we are the earlier we will see young frogs and toads leaving the water. In the north, the bullfrog tadpole spends parts of three summers in the water, but in the south it becomes a frog the second summer. The temperature of the water and the amount of food obtained are important factors in the development of tadpoles. It is possible to retard the growth of the tadpoles of common frogs so that they do not become frogs until the summer after the eggs were laid if they are fed little and kept in cold water. Some salamanders spend all of their lives in the water.

**The principle of recapitulation** is that an animal or plant in passing from the egg to the adult recapitulates or repeats the stages which its ancestors passed through in their development from the first single celled forms of life. In the animals the single celled egg represents the protozoan stage, the gastrula represents the jelly-fish stage, and the tadpole of the frog represents the fish stage. This principle must of necessity be very imperfect. Many structures are not represented, some are omitted, and some appear too soon or too late; but the principle has been of great value in tracing the relationships of the present forms of life. Animals which are closely related have similar life histories. A comparison of the development of embryos is, therefore, a test of relationship.

### OUTLINE-SUMMARY

Alternation of generations does not take place regularly in the reproduction of animals. Because it is possible to let one type represent all animals, and because frogs and toads are typical, we have chosen the development of the tadpole as a type of animal reproduction.

The eggs are laid and fertilized in water. Development begins with equal cell division which becomes unequal as the blastula and gastrula are formed. They are not perfect for eggs which have much yolk.

Toad tadpoles develop and emerge from the water in July. Frog tadpoles leave the water later.

The principle of recapitulation is of value in determining the relationship of animals.

**Review Questions.**—In what ways is the reproduction of animals simpler than that of plants? Why are frogs and toads good types for the study of animal reproduction? At what season are frog's eggs developed? When are they laid? Why do frogs and toads sing? Describe the appearance of a frog's egg. How does the vegetative pole differ from the animal pole of the egg? How is the blastula formed? How is the gastrula formed? How does the presence of yolk make the gastrula imperfect? Describe the growth of a tadpole into a frog. What is the principle of recapitulation?

### SUGGESTED STUDENT ACTIVITIES

**Laboratory Suggestions.**—The author would have preferred to have placed this study at a time when it would be possible to collect living material for study. The life history may be studied in the laboratory from preserved material, models, and charts. Lantern slides may be of great help also. When spring comes make a study of the tadpole in its natural environment.

Tadpoles of the bullfrog may be kept in the laboratory aquaria the year around. If kept in cold water and fed sparingly, the tadpoles of the common frog may have their growth retarded until after mid-winter.

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## UNIT V. THE CONTROL OF THE ACTIVITIES OF LIVING THINGS

It is common knowledge that our activities are controlled by our brain and nervous system. But do we know how a plant does its work? Even the simplest plants and animals are able to do all of the things which are necessary in their lives, and yet they have no brain. Some of the simplest animals have no nerves, and no plant has nervous tissue.

If we wish to study the nature of nervous activity, we may do well to begin with the simplest forms of life which show ability to make responses to the conditions of the environment which influences their lives. This will show us some of the ways in which protoplasm is able to keep in constant adjustment to its surroundings. As we study more complex activities, we come to study tissues which act under the control of nerves. Then we may compare the simple creatures which live without brains and those which have brains. By this study we may gain a broader understanding of how our bodies are controlled by our brains and nerves than we should if we had nothing with which to compare our activities.

## PROBLEM 1. HOW ARE THE LIVES OF PLANTS AND PROTOZOANS CONTROLLED?

**General Questions.**—Is there any difference between the responses of living and non-living things? What are tropisms? What are some specific examples of the tropisms of plants and protozoans? Is there any essential difference between the responses of protozoans and higher animals?

Perhaps you have wondered how a tree grows up, spreading its branches and leaves in the sunlight, and how, at the same time, it sends its roots in the opposite direction; or you may have wondered how a creature so simple as an ameba can obtain food, find a good place in which to live, and escape from an unfavorable situation? We say that their activities are made up of a series of responses. But what is a response?

A **response** is an action resulting from a *stimulus*. If an image is cast on a photographic plate, a chemical action takes place, due to the action of light on silver salts. *The light is the stimulus and the reaction is the response.* The responses of living things are more complex than those of inanimate things, but it is difficult to draw the line of separation. Certain biologists, called *mechanists*, believe that when we have gained sufficient knowledge, all of the responses of living things can be explained in physical terms. Others, called *vitalists*, believe there is a vital force or principle in living matter that can not be analyzed physically. This conflict can not be settled at present because the proofs are not complete.

The simple forms of life make very definite responses to stimuli. In most all cases a certain stimulus is followed, without exception, by the same response. For instance, seedlings always turn green in light; seeds germinate in spring if conditions are right, or may germinate at some other time if moisture, temperature, etc., are favorable; but if these conditions are not right, they do not germinate. These dependable responses have been carefully studied by biologists. They are called tropisms.

**Tropisms** (Lat. *tropus* = to turn).—The principal kinds of tropisms are as follows:—

Geotropism, reaction to gravity.

Hydrotropism, reaction to water.

Phototropism, reaction to light.

Chemotropism, reaction to chemicals.

Thigmotropism, reaction to touch or contact.

Thermotropism, reaction to heat.

**Geotropism.**—Plant roots grow downward, and stems grow upward, hence root growth is said to be *geotropic* and stem growth *negatively geotropic*. If a young plant is placed in a rotating machine in a horizontal position with its stem and roots along the axis of rotation it makes no response. If the disk is stopped, the entire stem bends upward, but only the tips of the roots grow downward.

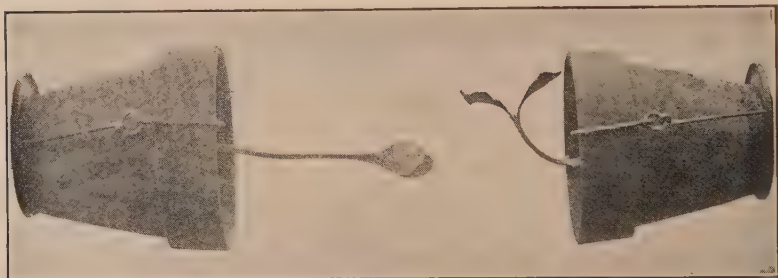


FIG. 155.—Two photographs of a squash seedling to show geotropism. When the flower pot was rotated the plant grew straight out, but when it was stopped the plant bent upward.

(See Fig. 155.) Geotropism may produce movement in a stem, but it merely influences the direction of growth in the root. Could roots already formed in the ground move in response to tropic influences? Obviously, they could not, for the soil holds them firmly. Thus we see that the responses to gravitation are convenient for the best interests of the plant.

**Hydrotropism.**—Roots grow toward moisture in the ground. If a box containing a plant is kept properly moistened on one end and the other is too dry, the root growth will be more abundant toward the

moist end. This is an example of *positive hydrotropism*. We are not sure that all roots exhibit this characteristic, or that they all grow toward water, but we know that some do. (See Fig. 156.)

**Leaves are sensitive to drought.** Those of corn roll up in order to expose less surface to the air. Fruit trees may shed their leaves. The leaves of the olive stand in a vertical position so as to avoid presenting a broad surface to the heat of the sun. The compass



FIG. 156.—A geranium cutting arranged to show hydrotropism. The dry soil is to the left, and the moist soil to the right. There is some reason to doubt that an experiment of this kind really illustrates hydrotropism. What do you think about it?

plant grows with its leaves vertical and the surfaces facing east and west. In this case only the edges of the leaves are exposed to the hot, midday sun. In the olive and the compass plant the leaf position is not changed but remains permanent throughout the summer (Fig. 157).

**Phototropism.**—The struggle of plant and leaf stems to place the leaves in the best light has been mentioned before. Leaves are

*positively phototropic*. When they grow very close together, as on vines climbing a wall, they are so arranged that the maximum



FIG. 157.—Phototropism for drought resistance in the compass plant. The leaves point north and south. In taking the picture the camera was pointing directly west, and the sun was at the noon position. Note the shadows on the leaves.

amount of light is received and shading is avoided as much as possible. This results in the formation of a *leaf mosaic*.



In the morning the young sunflower plant faces east. It keeps its head toward the sun all day long, so that at evening it faces west. The broad leaves are so arranged that this movement furnishes the maximum illumination.

Many plants "sleep" at night,—*i.e.*, they fold their leaves at the approach of darkness. Wood sorrel, beans, clovers, and the locust tree are among the best known examples. The advantages of this



FIG. 158.—Two photographs to show phototropism in one of the milkweeds which "sleeps" at night.

response are not fully known. It has been shown that folded leaves are in less danger of frost than open ones, but this advantage can not apply to tropical plants which fold their leaves. (See Fig. 158.)

Gourds, jimson-weeds, and four-o'clocks open their flowers in the evening. Morning-glories and squashes open their flowers in the morning. Others like the water lily close their petals when the sunlight is bright at midday and open them again toward evening.

Night blooming flowers are usually white and are visited by night-flying insects, such as the hawk moths. Can you mention some other examples of phototropism in plants?

**Euglena** is a protozoan containing chlorophyll and is a favorable animal for the study of *phototropism*. If the light is too bright, it moves away. If too dim, it moves toward the light. If a dish is arranged so that one side is very light and the other shaded, it will occupy a position between the two extremes. This is the optimum where photosynthesis takes place most favorably. (See Fig. 62.)



FIG. 159.—Two views of a sensitive plant—before and after being touched. The petioles are raised and lowered by the action of pulvini as in the bean. Can you secure some leaves which have pulvini and study them?

**Thigmotropism.**—The best example of movement in response to a mechanical stimulus to be found among plants is the case of the common sensitive plant, *Mimosa*. It may be grown from seed in the laboratory. When it is the size of the plant shown in the illustration, its leaves may be made to collapse if it is touched with the finger. In a few minutes it regains its normal appearance, when it may be made to collapse again. This is an example of *negative thigmotropism*.

We have seen how twiners and tendril climbing vines wrap around their supports as a result of contact stimulus (see study on stems). This is an excellent example of *positive thigmotropism* among plants. It is explained by what is called *cell turgor*. When a cell is filled with sap to the extent that it is rigid, it is said to be *turgid*. When a cell is in the opposite condition, it is *flaccid*. If the pressure of the cell

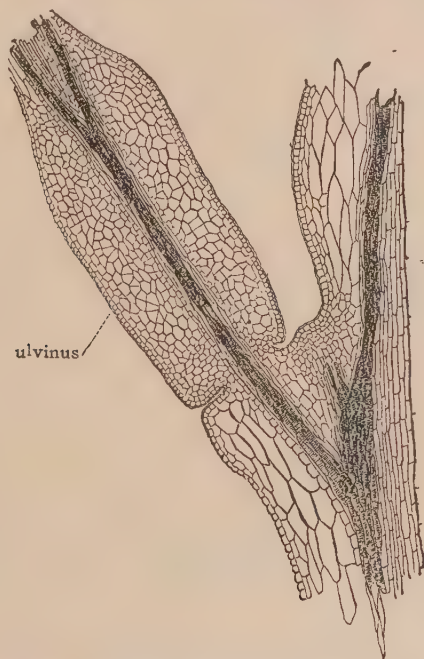


FIG. 160.—The pulvinus at the base of the leaf stem of the sensitive plant. Note the large cells which it contains, also the constriction near where it joins the plant stem. (Green.)

sap on one side of a stem or twiner is increased, or if it is decreased on the other, the stem will be bent. The leaves of the sensitive plant have an enlargement at the base of each leaf stem. It is called the *pulvinus*. By changes in the turgidity of its cells, the leaf is moved. Many other plants have a pulvinus at the base of each leaf. It is the mechanism with which the sensitive plant moves its leaves (Figs. 159 and 160).

**Ameba** (Fig. 161) has many tropisms, some of which we shall mention without extended discussion. If a moving ameba is touched with a pointed object it puts forth new pseudopodia (false feet) and moves away from the irritation. If it comes in contact with food it puts forth pseudopodia and surrounds it. Thus, it may respond positively or negatively to contact. It reacts negatively to



FIG. 161.—Positive tropism in ameba, showing how one followed an encysted euglena in an effort to engulf it. At 3 and 5 the cyst rolled out of contact and was nearly lost. Note the changes in direction taken by the ameba and the persistency of the ameba's pursuit. The cyst was lost at 9 by the interference of another protozoan. (*Jennings.*)

sugar, salt, and many other chemicals in solution. At freezing temperature no activity takes place. As the temperature is raised the animal becomes more and more active until about 85°F. is reached when its activity again diminishes until about 90°F. is reached when activity ceases. Thus, there is a *minimum*, *optimum*, and *maximum* temperature to which amebas respond. The opti-

mum being the temperature best suited to its activities. If a weak electric current is passed through an ameba it contracts and moves toward the negative pole. It responds negatively to light unless

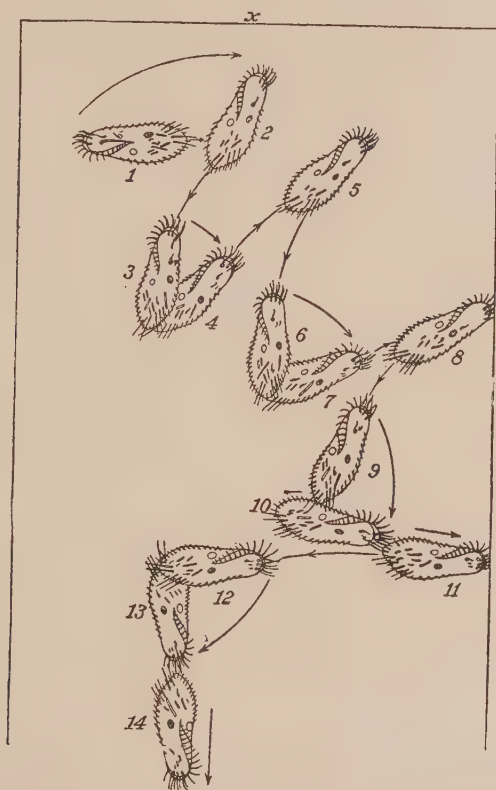


FIG. 162.—Trial and error as illustrated by a ciliate trying to escape from heat which was applied at X. This one was able to turn in only one direction, namely to the right. It reversed its direction of movement at 2 and 5 because of the heat; and reversed at 8 and 11 because it came into contact with the side of the containing vessel. At 14 it escaped. (Jennings.)

the light is very strong, when it stops moving and contracts. We have pointed out five tropisms of the ameba. Can you name them?

**Paramecium** is a representative of a group of fast swimming protozoans which are sometimes called the *ciliates* (possessing hair)



because they wave numerous hair-like processes as they propel themselves through the water. If a ciliate comes in contact with an object or an unfavorable environment, it stops, reverses the movement of the cilia and swims backward a short distance; then turns and goes forward in a different direction. If it again encounters the unfavorable stimulus, it repeats the process until it finally escapes. This is called the *method of trial and error*, and the negative response is called the *avoiding reaction*. No matter how many times it may fail, it continues to try again and again (Fig. 162). If one of the higher animals, after repeated trials, fails to accomplish its purpose, it seeks a new method; but ciliates have no memory or understanding of what they are doing. They have only one response which they can make to a stimulus, and it is always the same.

### OUTLINE-SUMMARY

The simple activities of plants and animals are responses to stimuli.

Tropisms: geotropism, hydrotropism, phototropism, thigmotropism.

Protozoans showing tropisms: euglena, ameba, paramecium.

Plants showing tropisms and mentioned in this problem: squash, geranium, compass plant, corn, fruit trees, olive, milkweed, vines, sunflower, wood sorrel, beans, clovers, locust tree, gourds, jimson weeds, four-o'clocks, morning-glories, squashes, water lily, sensitive plant.

**Review Questions.**—How are responses and stimuli related to each other? What are tropisms? Give some examples of geotropism. What experiment may we perform to show that roots grow toward water? How do some leaves resist drought? Why do plants form leaf mosaics? Why are night blooming flowers usually white? How does euglena show phototropism? How does the sensitive plant respond to touch? By what mechanical means does it move its leaves? Name the five tropisms which were mentioned in the discussion of ameba. How do ciliated protozoans illustrate the method of activity called trial and error?

## SUGGESTED STUDENT ACTIVITIES

**Laboratory Work.**—**Geotropism** may be illustrated in various ways by plants, especially seedlings. **Hydrotropism** may be shown by plant roots, but good results are difficult to get.

**Phototropism** is easily shown by placing a young plant where the light comes from one side only. The seedlings of the squash and pea are excellent.

**Thigmotropism** may be demonstrated before the class by touching the leaves of the sensitive plant, and by touching an earthworm or a frog with a bristle. Touch the animals in various places and determine if they are equally sensitive in all parts of their bodies.

**Thermotropism**, with its minimum and optimum effects, may be shown by preparing a trough as shown in the illustration (Fig. 163) and placing in it some water-inhabiting animals. The temperature of the warmed end should not get

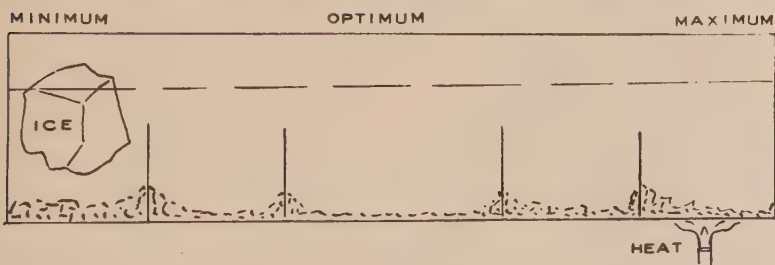


FIG. 163.—Diagram of a tank to show how animals seek optimum conditions in which to live.

above  $98^{\circ}\text{F}$ ., and the temperature of the end which is cooled with ice will be about  $34^{\circ}\text{F}$ . The partitions should go to the bottom and may be held in place with sand. They are to prevent convection currents from warming the entire trough—or cooling it. Place a thermometer in each compartment and record the temperatures on the blackboard. This demonstration should be started about two hours before it is to be shown to the class. There will be considerable difference in the results obtained with different kinds of animals. The more active they are the sooner they will respond.

**Trial and error** reactions may be observed by watching paramecia under a microscope. Place some scum in the water where they are and note how they collect around it. Place a very small crystal of salt in the drop where they are and note how they act in reference to it. The entire class may work at this if there are enough microscopes.

## References

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 Payne, *Experimental Botany*, American Book Co.  
 Osterhout, *Experiments with Plants*, Macmillan Co.

## PROBLEM 2. HOW ARE THE ACTIVITIES OF ANIMALS CONTROLLED?

**General Questions.**—Why are our activities more efficient than are those of the single celled animals? What are nerve cells like? How does the frog's brain compare with ours? What are the parts of the brain? How is the brain connected with the eyes, ears, and other organs of the head? How is the brain connected with the rest of the body?

PROTOZOANS and PLANTS have no nervous system, yet we have shown that plants are *irritable*—*i.e.*, they are able to respond to a stimulus, and that protozoans are composed of a single cell the functions of which are general, each cell being able to carry on digestion, locomotion, respiration, and sensory activity, all of which are delegated to special cells in the higher animals.

**In human affairs** we have come to regard specialization as necessary. We call a plumber when we wish to have some plumbing done, and a lawyer when we wish for legal advice. Experience has shown that specialists do their work better than men of all work. Because of this fact we have the expression “Jack of all trades and master of none”. If we think of ameba and paramecium in this regard, we shall not expect them to be very efficient animals. It is true that they do not do any one thing very well, but because of the way they live, they are able to continue to exist. •

**Plants** have developed many kinds of tissues, but have not developed the special kind of cells of which this study is to treat. Plants have their roots in the ground and do not move about. They do not need muscle cells. One of the chief uses of nerves is to cause muscles to perform. Perhaps this is one of the reasons why plants have no nerve cells.

**The bodies of animals** are composed of *organs*. Each organ is a special structure, composed of special kinds of cells, with a special work to do. The heart is an organ. It is composed of muscle cells which by contracting force the blood through the arteries. Other examples of organs are the eyes, ears, lungs, kidneys, stomach, and feet. Sometimes an organ performs more than one function as in the case of the liver which does several kinds of work for the body. Among its duties are secretion of bile, purification of the blood, storage of glycogen, oxidation of proteins, etc.

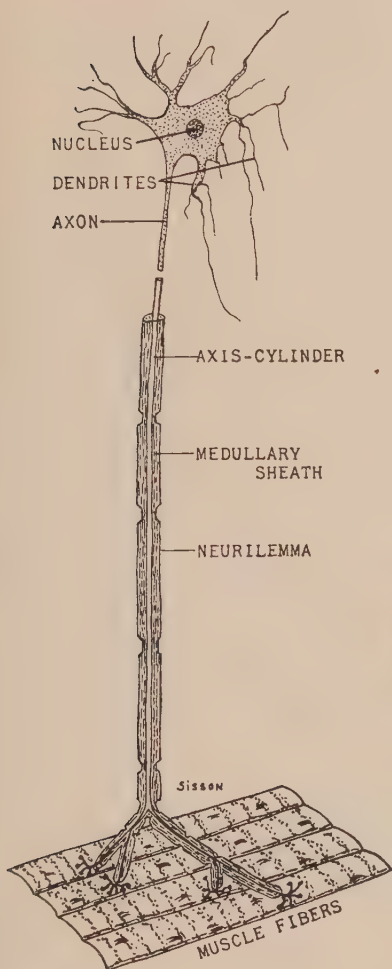


FIG. 164.



FIG. 165.

FIG. 164.—A typical motor nerve cell with all of its parts. The axon is cut near the cell. Some axons are very long. Greatly enlarged.

FIG. 165.—Diagram of the nervous system of man to show how the nerve fibers connect all parts of the body through the spinal cord and the brain.

**Each organ** is connected with special cells the fibers of which extend to all parts of the body. These cells are *nerve cells*. They have just one function to perform. It is to carry messages. Each nerve cell is a one way track. It carries messages either to an organ, or from it. Since all nerves are connected with the brain, either directly or indirectly, we think of nerves as carrying messages to or from the brain. If they carry messages out, they are called *motor nerves* because many of them go to muscles and cause movement. If they carry messages from some organ as the eye or skin to the brain, they are called *sensory nerves* because these are organs of sense; however all sensory nerves do not arise in sense organs and all motor nerves do not run to muscles. \*

**A typical motor nerve cell** is shown in the illustration (Fig. 164). Note that it has a *cell body* and contains a *nucleus* the same as any cell. Its special characteristics are that it has collecting fibers which receive impulses from other nerves and also distributing fibers which carry impulses to organs or to other nerves. The collecting fibers are called *dendrites*. The distributing fiber (or fibers) is called an *axon*. The axon is covered with a white, fatty substance called the *medullary sheath*. It is believed to act as an insulator to prevent the escape of the impulses which are traveling over the axon to other axons or to dendrites. The medullary sheath is covered by an outer covering called the *neurilemma* along which constrictions appear at intervals. Either the medullary sheath, or the neurillema, or both may be absent on some axons.

**The nervous system** (Fig. 165) is composed of all of the nerve cells and their processes which are in the body. It is customary to think of the brain and spinal cord as the *central nervous system* and the rest of the nerves as the *peripheral* (surface) *nerves*. If we wish to gain a better idea of the brain and nerves of man, we may begin by considering the nervous system of the frog. Its nervous system is much simpler than ours, and ours may be better understood if we compare it with that of the frog. Learn the names of the parts which are labeled on the figure. (See Figs. 166 and 167.)

**The frog** has a distinct skull cavity containing a brain which may be divided into three main divisions: *forebrain*, *midbrain*, and *hind-brain*. The forebrain is composed of two *cerebral hemispheres*



(*cerebrum*) and two *olfactory lobes*, each of which receives a nerve (*olfactory nerve*) from the smelling organs (*olfactory capsule*) in the nose cavity. The midbrain is composed principally of the *optic lobes*. They are very large in proportion to the rest of the brain and lie above the *optic chiasma* where the nerves from the eyes cross. The hindbrain is composed of the small *cerebellum* and the *medulla*.

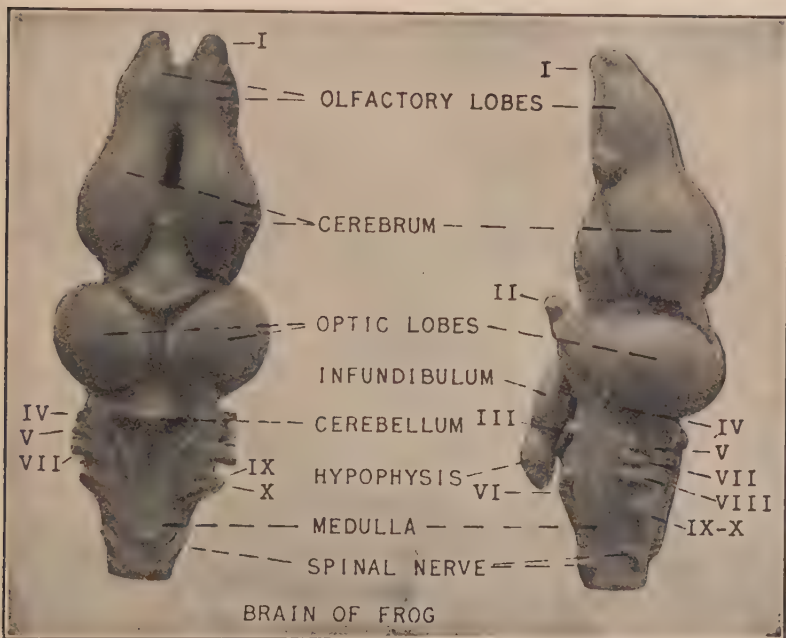


FIG. 166.—Dorsal and side view of the brain of the frog. The cranial nerves are numbered I to X. (Author's photographs of Ward's models.)

**In man** the cerebrum is greatly enlarged and extends forward and backward over the greater part of the rest of the brain.

The cerebellum is also enlarged and lies beneath the back part of the cerebrum. The brain is flexed (bent) above the medulla so that the long axis of the cerebrum is at right angles to the medulla, whereas in the frog they are parallel.

The medulla is continued down the back, dorsal to the vertebral column, as the *spinal cord*. It is about seventeen inches long and

about three-fourths of an inch thick. It is nearly cylindrical and tapers toward the lower end. Fissures run along both the front and back sides of the cord and nearly divide it. A cross section of the cord shows that it is composed of *white fibers* and *gray cells*. The fibers are situated around the outside, and the nerve cells are in the center of either half and form a band across the middle. (See Fig. 169.)

**The cranial nerves** (Figs. 166, 167, and 168) are those which are connected with the brain. Nerves which are connected with the

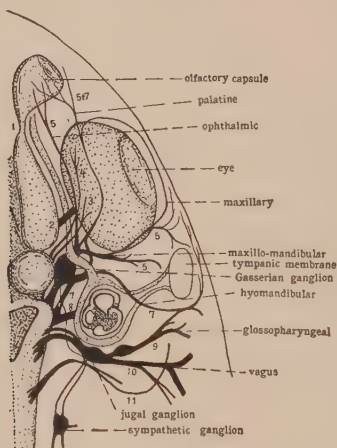


FIG. 167.—The right half of the head of the bullfrog to show the brain and cranial nerves. The nerves are both named and numbered. The fifth nerve is merged with the seventh, and they have the following named branches: palatine, ophthalmic, maxillo-mandibular, maxillary, and hyomandibular. These names need not be remembered. All of the parts are natural size.

spinal cord are called *spinal nerves*. In the frog there are ten cranial nerves, and the first spinal nerve which is numbered 11 in the figure, which course through the head. They have the same names, and do nearly the same work, as in man. It will be profitable to compare the cranial nerves of the frog with those of man as they are shown in the two figures. Man has an eleventh and a twelfth nerve which are not present in the frog, but the first spinal nerve of the frog may be compared to the twelfth in us. The twelve cranial nerves, and the work which they do, are listed in the following table.

## TABLE OF THE CRANIAL NERVES AND THEIR DISTRIBUTION

- I. Olfactory, from olfactory bodies.
- II. Optic, from retina of eye.
- III. IV, VI. Eye motor nerves, to eye muscles.
- V. Trigeminal, to and from various parts of the head.
- VII. Facial, to and from the face.
- VIII. Auditory, from the ear.
- IX. Glosso-pharyngeal, to and from the tongue and pharynx.
- X. Vagus, to and from the stomach, larynx, lungs, heart.
- XI. Spinal accessory, joins the vagus, and to shoulders.
- XII. Hypoglossal, to and from the tongue.

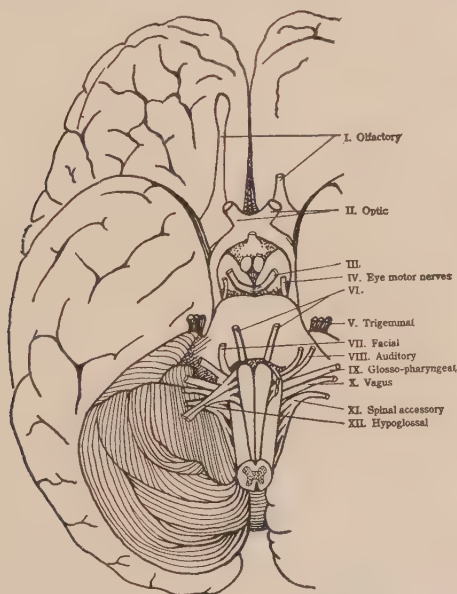


FIG. 168.—Ventral view of the brain of man to show the cranial nerves.

**Spinal Nerves.**—Thirty-one pairs of spinal nerves join the spinal cord in man. Each divides before reaching the cord, into a dorsal and ventral branch called *dorsal* and *ventral roots* (sometimes called posterior and anterior roots respectively). The posterior branch always contains a nerve knot or *ganglion*. The ventral branch does not. The dorsal roots are sensory, and the ventral roots are motor.

We have seen how the head and the organs which it contains is supplied with the cranial nerves. In the same way all of the body, except the head, is controlled by the spinal nerves. They go to every organ of the body. If the nerves which go to and from an organ are cut, the organ is unable to do its work. So we see that the activities of animals are controlled by the nervous system. The greater efficiency of the higher forms of animal life is due more to the fact that they have a good nervous system than to any other thing. We may also say that the more complex the nervous system is the more efficient is the animal which possesses it.

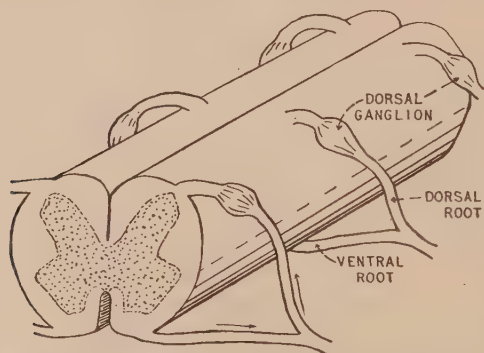


FIG. 169.—Stereogram of the spinal cord to show how the spinal nerves are attached. Note that the dorsal nerve has a ganglion and the ventral one does not. Note that the cord is nearly divided into a left and right half by a narrow, deep, dorsal fissure and a broad, shallow, ventral one. The distribution of the gray matter in the middle of the cord is shown in stippling.

### OUTLINE-SUMMARY

Protozoans and plants are without a nervous system. Animals and plants have special cells to do special work. This is specialization and gains for the plants and animals a higher degree of efficiency in carrying on their lives than they would have if they had all cells alike.

Special groups of cells which do a special kind of work are called organs. Organs are controlled by nerves.

Description of a typical nerve cell.

Comparison of the brains of frog and man.

Cranial and spinal nerves.

**Review Questions.**—Do all living things have nerve cells? How do they control their activities? Why is a Jack of all trades often a master of none? Why do not plants need nerves? What are organs? How are they controlled? Compare the two kinds of nerve cells. Describe a typical motor cell. Of what is the central nervous system composed? The peripheral? Describe the brain of the frog. Compare the brain of man with that of the frog. Cranial nerves are known by name and by number. How many of them do you know? What do the spinal nerves do? How do we know that an organ can not work if it has no nerves?

### SUGGESTED LABORATORY WORK

Models of the brains of animals and of the spinal cord may be purchased from the following dealers:

Ward's Natural Science Establishment, Rochester, N. Y.

Denoyer-Geppert Co., Chicago, Ill.

General Biological Supply House, Chicago, Ill.

These may be studied and sketched in the laboratory.

If time permits it may be profitable to dissect the frog. The bullfrog is recommended because of its larger size. Directions are given in Atwood, *Problems, Projects, and Experiments in Biology*, and more complete directions may be found in Atwood, *Comparative Vertebrate Dissection*. Both published by P. Blakiston's Son & Co.

### References

Galloway and Welch, *Zoology*, P. Blakiston's Son & Co.

Holmes, *Animal Biology*, P. Blakiston's Son & Co.

Hough and Sedgwick, *The Human Mechanism*, Ginn & Co.

Linville and Kelly, *General Zoology*, Ginn & Co.

### STUDY 3. THE STRUCTURE AND USE OF THE SENSE ORGANS

**General Questions.**—How many senses do we have? What are they called? Do animals have the same organs? How do we use the sense of touch? What organs do animals have for touch? Why are taste and smell called chemical senses? Can an earthworm receive sensations of vibration? What is the structure of an ear? How does the ear work? What is light believed to be? How does a lens work? What animals have the simplest eyes? What is the structure of the eye? How may we show how the eye works?



We shall divide this study into four problems each of which deals with a group, or type, of sense organs, but we can not study all of the kinds of these organs which animals have.

One of the great advantages which the higher animals have over the lower is that they have *sense organs*. These structures are made to receive impressions from the physical world about us. How little we would know about the world if we had no hearing, sight, smell, or taste! Perhaps our most important sense organs are our eyes and ears. We do not know how many kinds of organs of sense there are in the biological world, but we do know that some animals have some kinds which we do not have. Nor can we know just what effect the sense organs of animals have on them, except by inference that those which are similar to ours have similar uses to them.

We possess six senses each of which is dependent upon a special sense organ. They are *touch, taste, smell, hearing, balance, and sight*.

**Problem 1.—What are the organs of the sense of touch?**

**Touch** is the simplest and most fundamental of these senses. We have only our fingers as special organs of touch, but the tongue and parts of the face are very sensitive and are often called upon by us to give information about the quality of an object. Some animals have very highly developed organs of touch. The insects and crustaceans (crabs, crayfish, and lobsters) have *antennæ* which are the most remarkable and variable of touch organs (Fig. 170).

*Tentacles* are somewhat similar structures found among the worms and squids and their relatives. (See Fig. 171.)

**Problem 2.—What are the chemical senses?**

The senses of taste and smell are spoken of as the *chemical senses* because their operation depends upon chemical action. Very small quantities of certain gases in the air stimulate special cells in smelling organs, called *olfactory organs*. The method by which one odor is distinguished from another is not very well understood. The sensory cells in olfactory organs are very much alike and are simple in structure, so far as can be seen with the aid of the microscope.

The special organs of taste are known as *taste buds*. In mammals they are found chiefly on the tongue. In man the buds at the tip of the tongue give the qualities of *sweetness* and *salt* the most readily; those at the base of the tongue, *bitter*; and those along the



FIG. 170.—Photograph of the head and antennæ of a lobster. Note that it has two kinds,—a pair of long single ones and a pair of short double ones.



FIG. 171.—Photograph of a tube worm taken from its burrow. They live in the mud at the bottom of the sea and extend their tentacles from the burrow. This worm uses its tentacles, not only to feel with, but as grasping and respiratory organs as well.

edges, *salt* and *sour*. What the sensations of taste in other animals are like, we do not know. We simply know that they taste. A substance, in order to be tasted, must be in solution. Insoluble substances like marble, granite, or sulphur crystals have no taste. Why?

Unless we have had scientific instruction in the matter, our ideas of smell and taste are apt to be far from correct. We have but four taste qualities, but very many kinds of smell may be detected. When we eat food, we speak of the "taste" of it. What we frequently do



FIG. 172.—Photograph of the ear of a grasshopper. It is the light area just below the second pair of wings. Enlarged.

mean is the "smell" of it. The smell of our food is of much more importance to us than the taste.

**Problem 3.—What is sound, and what is its relation to animal life?**

To the biologist sound is a sensation. To the physicist it is a vibration which may be detected by the ear. Our ears are limited as to the range of vibrations which they may perceive. It is probable that many vibrations which are unnoticed by us are heard by some of the lower animals..

### How do animals hear?

If you steal up on an earthworm when it is extended from its burrow and jar the earth in its vicinity, it will withdraw rapidly. The jar is a vibration in the soil and is received in some way by the nervous system of the worm, but no special sense organ for the detection of vibrations can be found.

**The ears of the grasshopper** (Fig. 172) are situated on each side of the first abdominal segment. Each consists of a membrane stretched over the side of the first abdominal spiracle. It is supplied with nerves which carry impulses to the ganglia in the thorax. Such an organ is called a *tympanum* (Gr. *tympanum* = a drum). Tympanal organs are found in various places on other insects. Insects and vertebrates are the only animals which have true hearing organs.

**The Balance Organ.**—In the vertebrates the organ of hearing and that of balance are situated together in the ear. The ear consists essentially of a cavity called the *labyrinth* which is lined in places with sensory cells. In fish it is partly divided into two chambers,—the *sacculus* and *utricle*. Connected with the utricle are three *semicircular canals* arranged at right angles to each other so that two are vertical and one is horizontal. All of the higher vertebrates possess the utricle and its three canals arranged essentially as they are in the fish. This part of the ear has nothing to do with hearing but is an organ of balance. If this organ is rendered functionless the fish can not swim in an upright position.



FIG. 173.—The labyrinth of the ear to show the three semicircular canals and the coiled cochlea. (Hamaker.)

**The hearing organ** of the ear is not found in the lower forms of vertebrates, and reaches its climax in mammals. It is an outgrowth of the sacculus and is coiled like a snail shell to conserve space in the head. Because of its shape, it is called the *cochlea* (Lat. snail shell). (See Figs. 173, 174, and 175.)

Two partitions extend throughout the entire length of the cochlea and divide it into three parallel, coiled chambers which are filled with fluid. The middle chamber contains the sensory cells which receive the sound vibrations. They are situated on one of the longi-

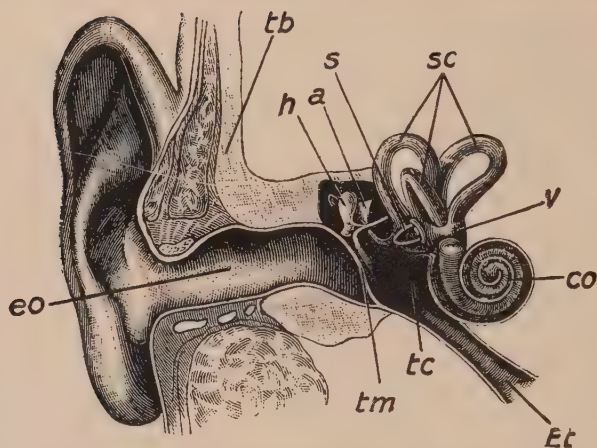


FIG. 174.—Section through the human ear to show its parts. (Holmes.)

*Outer ear*

eo, external opening

tb, bone of skull

tm, tympanic membrane

*Middle ear*

h, hammer

a, anvil

s, stirrup

tc, ear cavity

Et, Eustachian tube

*Inner ear*

sc, semicircular canals

v, vestibule

co, cochlea

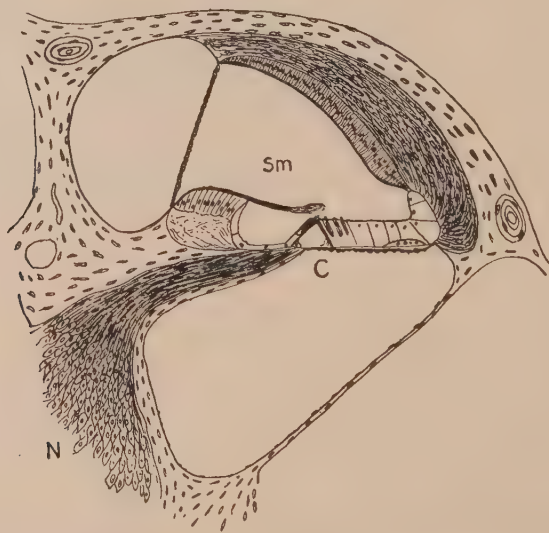


FIG. 175.—Cross section of the cochlea to show the three chambers into which it is divided. Sm is the middle chamber. The organ of Corti is just above C. N is the nerve tract and ganglion. (Hamaker.)



tudinal partitions of the cochlea and, together with other cells, make up the *organ of Corti*. Projecting into the fluid of the middle chamber, from each sensory cell, are about twenty rod-like processes which are believed to be the end-organs of hearing. The structures which we have just described make up the *inner ear*, and are the organs of hearing and balance.

The **middle ear** is a chamber connected with the mouth by a tube called the *Eustachian tube* after its discoverer, and is separated from the exterior by the tympanic *membrane*. Sound waves cause this membrane to vibrate, and the vibrations are transferred across the middle ear to the labyrinth by three small bones in mammals,

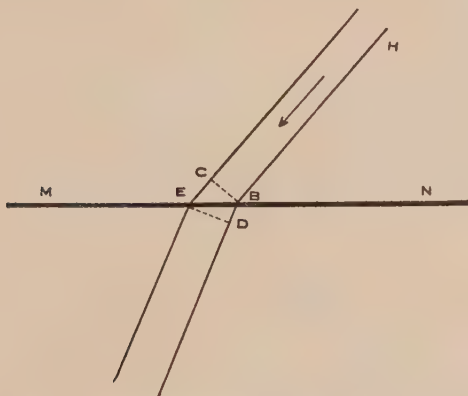


FIG. 176.—Diagram to illustrate refraction. The figure is explained in the text.

which act as a set of levers. They are called the hammer, anvil, and stirrup because of their shape.

The mammals are the only animals which have an outer shell to reflect the sound waves into the ear. In the frog the tympanic membrane is flush with the side of the head. Snakes, salamanders, and fishes lack both the outer and middle ear.

#### Problem 4.—How do animals see?

**Light** is believed to be a wave motion in the ether which is supposed to fill all space. These waves are a form of energy traveling in straight lines at the rate of 186,000 miles per second. At this rate light would travel around the earth at the equator about seven and a half times in one second.

**Refraction.**—The speed of light is not the same in all transparent substances. In comparatively dense materials like glass and water, it travels more slowly than in air, hence if a beam of light passes from air to water, or *vice versa*, it is bent at the line of junction of the air and the water. A reference to Fig. 176 will make this clear. If a beam of light falls on the surface of water  $MN$  at an angle as  $HBN$ ; when the wave front  $CB$  strikes the water, the side  $B$  will enter before the side  $C$ . Since light travels more slowly in water than in air, the side  $B$  will be at  $D$  when the side  $C$  enters the water at  $E$ . This will change the direction of the wave front and at the same time widen it. This behavior of a beam of light is known as *refraction*.

When a beam of light falls on the convex surface of a lens, it is refracted, or *focused*. The action of all lenses depends upon refraction.

**Seeing** has three important aspects. Animals which have no lenses in their eyes detect differences in intensity of light only.

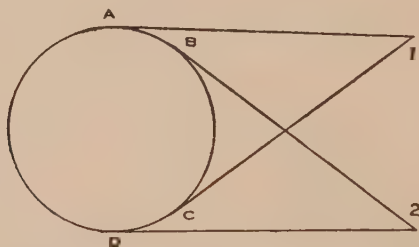


FIG. 177.—Diagram to show that two eyes at 1 and 2 see dimension and distance better than one, because each sees farther around the circle on one side than the other.

They do not see design or color of objects. *Intensity, design, and color* are the aspects of vision by which the eyes possessing lenses see. The shape or distance from the observer are further appreciated if the animal or person uses two eyes. This may be made clear by a reference to Fig. 177.  $ABCD$  represents a sphere. The eye at 1 sees the half sphere  $AC$ , while the eye at 2 sees the half-sphere  $BD$ , hence the surface is known to be curved, each eye seeing around the side a little farther than the other.

**Planarians** (Fig. 178) are flat worms which live in mud and decaying matter at the bottom of ponds. Near the head end of the body



FIG. 178.—Diagrams of euglena (left) and a planarian (right) to show the location of their light-sense organs. Can you secure some living specimens and study their eyes under a microscope? Note that there is a clear space in conjunction with each “eye”. Planarians seem to be cross-eyed.

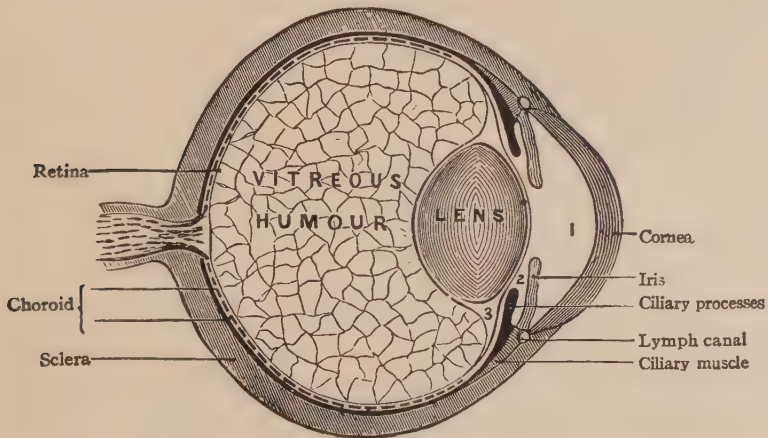


FIG. 179.—Diagram of the human eye. (Holden.)

are two pigment spots. They are organs of vision and are examples of the simplest kind of eyes.

The little green protozoan, **euglena**, has a small red spot near the head end of the body. We have seen in a previous study that euglena is very sensitive to light. The red spot is called an "eye". Planarians and euglena have no lenses in their eyes and see only differences in intensity of light.

The eyes of the **vertebrate animals** are all of the same type. A diagram of the human eye is shown in Fig. 179. Its essential features are the transparent *cornea*, the *aqueous humor*, the muscular *iris* for regulating the amount of light, the biconvex *lens*, the *vitreous humor*, and the *retina*.

If you wish to know how the lens of the eye works, secure a large lens from the physics department and hold a sheet of paper near it in such a way that the light from the window passes through the lens to the paper. By some adjusting, you can secure an image of the window or of objects outdoors. Note that the image is smaller than the objects which it represents, and that it is inverted. The image which is formed on the retina of the eye is of the same kind.

Fishes have spherical lenses in their eyes, and move the entire lens in focusing. Mammals have somewhat flattened lenses to which muscles are attached so that the lenses may be made thicker or thinner in focusing. These muscles are attached to the lens in the figure at 3. Fish eyes are adapted for short range vision, but the eyes of birds and mammals are equally good for long or short range work.

#### OUTLINE-SUMMARY

The sense of touch: fingers, tongue, antennæ, tentacles.

Chemical senses: taste, smell.

Ear organs: balance organ, hearing organ.

The sense of sight: eyes without lenses, eyes with lenses.

**Review Questions.**—Of what advantages may sense organs be to animals? What six senses have we? How do we use the sense of touch? What touch organs have insects and lobsters? For what does the tube worm use its tentacles? What sensations of taste may we experience? Which is more important, and why, taste or smell? What is sound? What two groups of animals are able to hear? How does the grasshopper hear?

What two sense organs are located in the ear? Which ear organ is well developed in the lower vertebrates? Which in the higher? Name the parts of the inner ear, middle ear, and outer ear. Compare the outer ear of the frog with ours. How does a lens work? Why are two eyes better than one? What are the three aspects of seeing? How much does an eye without a lens see? Name the parts of our eye and state the function of each part. How is the image formed on the retina? Compare our method of focusing with that of fishes.

### SUGGESTED STUDENT ACTIVITIES

Tentacles, cuticular hairs, and antennæ may be observed and in some cases sketched from life or preserved specimens.

Taste buds may be studied from charts, lantern slides, or models. Perhaps some student can make a model of a taste bud for the museum.

The well known experiment to show the relative importance of taste and smell by holding the nose and eating bits of apple, potato, carrot, etc., may be performed before the class.

Students may be asked to reproduce from memory a diagram of the human ear. It may be done on paper at the desks or on the board. Label completely.

The appearance of various eyes may be demonstrated by passing specimens from the museum case around the class.

A diagram of the human eye may be put in the notebook.

**Teacher's Demonstration.**—Illustrate image formation by holding a white cardboard near a convex lens (a reading glass will do) and securing an image of the window or some object outdoors. Note that the image is inverted and smaller than the object.

### References

- Hough and Sedgwick, *The Human Mechanism*, Ginn & Co.  
 Holmes, *Animal Biology*, P. Blakiston's Son & Co.  
 Galloway and Welch, *Zoology*, P. Blakiston's Son & Co.

### PROBLEM 4. HOW IS THE CENTRAL NERVOUS SYSTEM RELATED TO THE HABITS AND ACTIVITIES OF AN ANIMAL?

**General Questions.**—How would a frog behave if it had no brain? How would it behave if it had only the hind brain? How would it behave if it had all of its brain but the cerebrum? How does the nervous system of an earthworm control its activities? What is reflex action? What are automatic acts? What



are habits? How are they formed? Are they all bad? How does instinct control an animal's activities? What is the measure of an animal's intelligence? How does reasoning control activity?

We have learned something about the nervous system and the special sense organs, but we have not completed this line of study. The important part of this information is the relation of nervous



FIG. 180.—Two photographs of the leopard frog posed to show the normal position which the animal assumes when at rest and the prostrate position assumed when the brain has been removed.

control to the activities of the individual. We have seen how nerves control the activity of organs. Now we shall try to understand something of the control of the nervous system, as a whole, over the activities of the entire animal. The way an animal acts under certain circumstances is called its *behavior*. This is a problem in animal behavior.

Scientists have removed part, or all, of the brain of the frog to learn the function of each part. We may begin our problem with a review of the results which they have observed.

*If the entire brain of a frog is removed* and its spinal cord is left, it lies flat on its belly instead of supporting its body with its fore legs as does the normal frog. However, its hind legs are drawn up under its flanks in a natural way. The muscles in the walls of its arteries are relaxed, and it does not breathe. If a hind leg is moved the proper muscles contract and it is pulled back into position. If the skin is irritated along the side of the body the frog will make an effort to remove the irritation, but it does nothing unless it is stimulated.

*If the cerebrum and cerebellum are removed*, the frog maintains the same position as before; but the muscles of the blood system function, and respiration goes on.

*If the cerebrum only is removed* and all other parts left undisturbed, the frog sits erect. If its position is changed it maintains its position on its feet by crawling or turning over. It can be made to croak, and if thrown into water will swim. If it comes into contact with the bank it will crawl out and come to rest. It acts very much like a normal frog under stimulation, but it does practically nothing without stimulation, and does not vary its responses,—*i.e.*, it always gives the same response to the same stimulus no matter how many times it is repeated. If the lips are touched the animal tries to remove the irritation with its fore foot. It seems to be incapable of making any other response. The normal frog might try this method once or twice but would soon find another way to remove or escape from the annoyance. Animals without their cerebrums act like mere machines.

**The earthworm** lives in burrows in the ground and has no special sense organs; but if it is touched, it quickly contracts and moves, away from the stimulus. Nerve endings which are sensitive to contact are situated in the surface of the body, and from these nerve fibers pass in to the central nervous system. These fibers carry impulses from the surface of the body to ganglia in the central nervous system where the impulse is transferred through fibers to other nerve cells—motor nerve cells—which pass it on to muscles

in the body wall. This outgoing impulse causes the muscular contraction which draws the worm away from the irritation. A simple response of this kind is called a *reflex*, because the impulse is "reflected" from the ganglion to produce the response (Fig. 181).

**Reflex Action.**—The acts which are performed by the frog without a complete brain are reflex acts also. They are the simplest kind of control by nerves over the animal. *A simple reflex act is one that is performed as a result of an external stimulus and without con-*

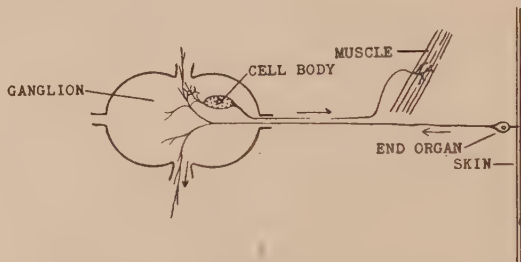


FIG. 181.—Diagram of a reflex action in the earthworm. An irritation of the skin is taken up by the end-organ and is carried to the double ganglion of the segment where the irritation occurs. From here it is distributed in various directions, but that part of the stimulus which is received by the fibers of the nerve cell shown is carried to the muscle causing contraction which is a response. In this action the other nerve centers are not necessarily involved.

*scious effort.* The individual may, however, become aware of the act after it has been performed.

**Automatic Acts.**—The muscular action which attends respiration, circulation, and digestion is not the direct result of an external stimulus, and hence these acts are not reflex. Such acts are, however, performed without conscious effort and are called *automatic acts*.

**Habitual acts** such as chewing, walking, talking, and riding a bicycle have to be learned; but after they are learned they can be performed without conscious control. They are the result of practice and are called *habitual acts*. When these acts are first performed considerable mental effort is required, and they are very imperfect. Finally, they become more perfect and can be performed with less attention of the higher mental powers. Thus the cerebrum is relieved of their control which passes to the lower centers in the medulla and cord.

**Habit.**—The lower animals live largely by reflexes; but as we ascend higher in the scale of animal life we find animals with more highly developed nervous systems, depending more and more upon habits for their body control. It is surprising to note how completely our lives are dominated by habits which may be good or bad. We arise in the morning, dress, eat our meals, and go about our daily tasks with very little thought about what we are doing. Most habits are formed in early life, and they grow constantly stronger as we become older. Therefore, it is of the greatest importance that we exercise the most care possible to form good habits of thought and conduct in the habit-forming period of our lives.

“The hell to be endured, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle in Jefferson’s play excuses himself for every fresh dereliction by saying, ‘I won’t count this time!’ Well, he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among the nerve cells and fibers the nerve cells are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out.”—James, *Psychology*.

**Instinct.**—A large percentage of the acts of animals are controlled by *instinct*. Birds do not have to learn to build nests. Nest build-

ing, incubation, and care of the young are instinctive acts. A hen that was hatched in an incubator and raised in a brooder will make just as good a mother the next season as one that has been raised by a mother hen and has had a chance to learn.

The social instincts of ants, bees, and wasps are very highly developed and can sometimes be slightly modified by the individual. M. Fabre, in experimenting with a digger wasp (*Sphex*) which preys on grasshoppers and always drags them into the hole to its nest by



FIG. 182.—A pair of purple martins, birds which have modified a nesting instinct. They prefer bird boxes to hollow trees.

seizing them by the antennæ, found that the wasp was able to drag the locust in by seizing the jaw appendages when the feelers were cut off, but could not sufficiently modify her instinct so as to seize a fore leg when the jaw appendages were also removed.

The purple martin and the tree swallow offer a good example of the change of an instinct by birds. They formerly built their nests in hollow trees and in openings in rocks. Now the purple martin prefers the bird boxes of boys to any other abode, and the tree swallow is often found nesting in such boxes, but its instincts have not so completely changed as have those of martins.

**Intelligence.**—An animal's intelligence may be measured by its ability to overcome or modify its instincts when special conditions arise. Intelligence involves memory and the ability to profit by experience. From this point of view the intelligence of all invertebrate animals is very low. Among the lower vertebrates, frogs and fish are capable of learning by experience, but only to a very limited extent. Fish may remember the location of a plate of glass in water after bumping into it several times.

"No fish is ever conscious of himself; he never thinks of himself as doing this or that, or feeling in this way or that way. The whole



direction of his mind is outward. He has no language and so can not think in verbal terms; he never names anything; he never talks to himself. As Huxley says of the crayfish, he 'has nothing to say to himself or anyone else'. He does not reflect; he makes no generalizations. All his thinking is in the present and in concrete terms. He has no voluntary attention, no volition in the true sense, no self-control." (Professor Sanford.)

**Reason.**—Acts which are performed in accordance with a plan which takes into account both the means to be employed and the end to be achieved may be said to be *rational*. If you wish to cross a stream, you may consider the possibility of crossing on foot, by raft, swimming across, or going around by way of a bridge. After considering the various possibilities a course of action is chosen, and the stream is crossed. This is a very simple example of reason. Although many scientists doubt the ability of animals to reason, a few believe that dogs and some other animals are capable of choosing between two courses of action to accomplish a purpose. Reason is the most complex faculty of the mind and is the most important mental advance of man over the lower animals.

### OUTLINE-SUMMARY

The behavior of the frog has been studied by removal of part, or all, of the brain. The brain is thus seen to control the activities of the body.

The earthworm and the frog without a brain perform acts which are reflexes.

Automatic acts are similar to reflexes, but their stimulus comes from within. They have to do with breathing, digestion, circulation, etc. They continue while we sleep, and we are not aware of their operation.

Habitual acts must be learned. They are very important in the lives of the higher animals and especially in man.

Instinct controls the lives of the lower animals much the same as habit does the higher, but instincts do not have to be learned.

Intelligence is measured by ability to control instinct and habit. Reason is the chief agency of such control.

**Review Questions.**—How does a frog behave without a cerebrum? Does this prove that the brain controls the body? How does the earthworm respond to stimuli? What is a reflex? What are automatic acts? Compare them with reflexes. How are habits acquired? When can we control them best, when we are old, or when we are young? Do you believe that the control of habit is as complete as Professor James says it is? Compare instincts with habits. To what extent may the digger wasp modify its instincts? How has the purple martin modified its instincts? How may we compare the degree of intelligence of animals? Give a simple example of reasoning.

### SUGGESTED SPECIAL ACTIVITIES

**Debate.**—A laboratory period may be devoted to a debate on the subject "Resolved that some animals can reason."

**Social Recitation.**—Give the members of the class a chance to relate their personal observations of animal intelligence.

Make a list of some of the habits which your school mates have and which can be corrected. Avoid personalities.

**Personal and private survey** of your good habits which you wish to improve, and of your bad ones which you wish to be free from should be made by each of you now.

### References

Hough and Sedgwick, *The Human Mechanism*, Ginn & Co.  
Bundy, *Anatomy and Physiology*, P. Blakiston's Son & Co.

## STUDY 5. HYGIENE OF THE NERVOUS SYSTEM AND SENSE ORGANS

**General Questions.**—What may we do to keep our nerves in good condition? How may we keep our skin in good condition? How may we keep our mouth and nose cavities in good condition? How shall we take the best care of our eyes? How may we keep our ears in good hygienic condition?

The hygiene of the brain and nerves is a problem of the entire body. If any organ is not in good condition, the nerves which run from it are disturbed. If the organ is injured or in bad condition, severe pains may be felt. Pain has a good influence, because it stimulates us to do something to better the condition of the organ which is causing the disturbance. A healthy body must have a well

working nervous system, and a hygienic nervous system must be supported by a healthy body. Therefore, the first thing to do is to keep all parts of the body in the best of condition all the time, if we are to keep our brain and nerves in good working order.

**Sleep** is the natural method of repair of tired organs and nerves. Many people do not appreciate the importance of regular hours of sleep. Next to sound sleep in importance is *digestion*. If we do not

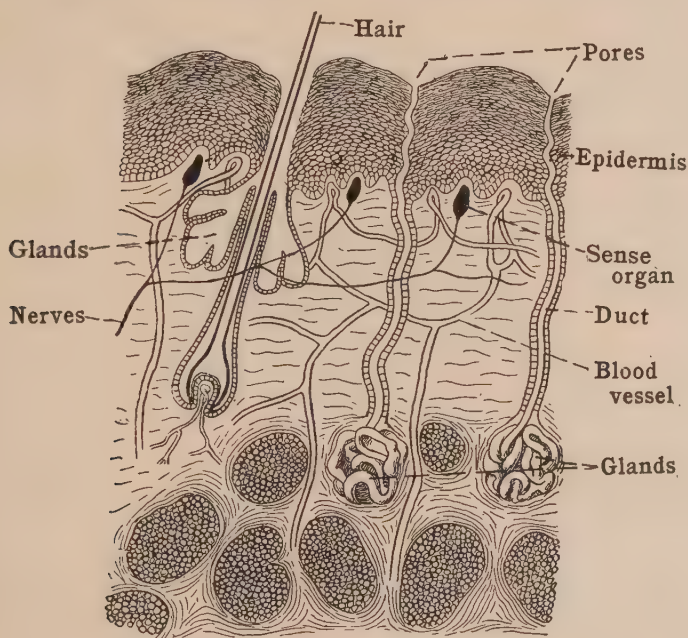


FIG. 183.—A section through the skin to show its structure. Note the sweat glands with long tubes, and the position of the sense organs just beneath the epidermis. (*Modified from Folsom.*)

keep our digestion in good order, we will be “nervous” and may have headaches. Nearly all headaches are caused by either indigestion or eye strain. Let us remember that when we have a headache, there is a pain in the brain. This is a warning to do something to correct the cause of the pain. To take a “tablet” for a headache is often the worst thing that we can do. The tablet

does not remedy the disordered stomach which is causing the pain. We must always get at the source of the pain.

We need not review the harmful effects of tobacco and alcohol on the nervous system. We have said enough in warning to wise students in a previous study.

**The hygiene of the skin** (Fig. 183) is also dependent upon the general condition of the body. The end organs of *touch* are located in the skin. Sensations of *heat*, *cold*, and *pain* also come from it. We can probably do nothing to improve the senses of the skin. The delicacy of touch of a blind person is due to experience, and not to a change in the end organs of the nerves.



FIG. 184.—View of the interior of the nose chamber to show the olfactory (smelling) organ. The olfactory nerve (1) comes in from above and distributes its branches as shown in 2. The turbinate bones are numbered 3 and 4. The fifth nerve is labeled 5. (Marshall.)

*Pimples* on the face are often caused by poor digestion. In any persistent case of pimples, a skin specialist and a stomach specialist should be consulted. Their treatment when very bad is too difficult to be trusted to the general practitioner.

*Baths* are excellent for the skin. They should be taken daily.

*Exercise* sufficient to cause the sweat glands to flow freely is also desirable. Exercise should be followed by a warm shower bath which is concluded with cold water.

**The hygiene of the nose and mouth** is important because *smell* and *taste* sensations arise in these chambers. Colds cause the greatest disturbances to the nose and throat. The nose should be flushed frequently with a normal salt solution while one has a

cold. If colds are not cared for, they may spread to the sinuses of the face and near the ears. Hearing may be impaired if infection spreads to the ears.

Indigestion may cause a bad breath and interfere with taste and smell sensations. Infected tonsils and bad teeth may cause similar disturbances. A coated tongue usually indicates imperfect digestion.

If the nose has been injured, the turbinate bones may be broken or bent. This may cause constant irritation in the nostrils. It should be corrected by a specialist. See the illustration.

**The hygiene of the ear** is usually a very simple matter. Keep it clean and let it alone. If too much wax, or hard wax, is troublesome, consult a physician. Do not poke hairpins and toothpicks into the ear opening.

*Infection* of the inner ear may result from the bacterial diseases. It may cause the loss of hearing, and in severe cases it may reach the brain and cause death. Consult an ear specialist if any pains are felt in the ear. Sometimes the treatment of these infections requires a long time to bring about a cure.

**The care of the eyes** is of great importance to students. Do not study while you have a headache or a pain in the eyes. Even a redness about the eyes is a sufficient excuse for laying the book aside. These symptoms are caused by unhygienic factors which are numerous, and difficult for the average optician to diagnose. It will be safer to go to an oculist, a medical doctor who specializes in eye diseases.

The eye is naturally an organ of long range vision, but students must do much close work. This keeps the muscles of the eyeball under strain. If it is prolonged, it may cause eye trouble, but do not be needlessly alarmed. Nature will give you the signal, if you study too hard. The light for reading and writing should always come from behind, and your work should be directly in front of you. This permits the light to come directly from the objects observed to the eye, and relieves the eye of unequal focusing, glare, and other irregularities.

*Eyeglasses* are worn to correct various kinds of defects. As we grow older, the lens loses its flexibility. In this case it may be necessary to wear a pair of glasses for reading and another for out-



door vision. *Far sight* is caused by the rays of light focusing beyond the retina, and *near sight* is caused by the rays of light focusing short of the retina. In near sight the person holds the paper too close to the eyes in an effort to place the image farther back against the retina. Both of these defects can be helped by the use of special lenses. See illustrations.

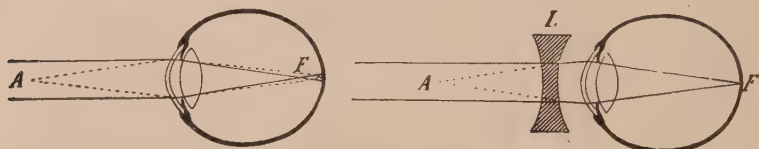


FIG. 185.—Diagrams to illustrate near sight (myopia) and the use of a reducing lens to correct it. Parallel rays of light focus at  $F$ . If a book is held at  $A$  the divergent rays of light will focus at the retina. When the lens ( $L$ ) is used all rays focus on the retina. (*Brubaker.*)

*Cross-eyes* or squint-eyes can frequently be remedied by a slight surgical operation. In some cases prismatic lenses may be used to bend the rays of light so that each eye will see the same picture.

*Astigmatism* is a defect of the eye wherein the lens or other parts are irregular causing the rays of light to be distorted. This prevents

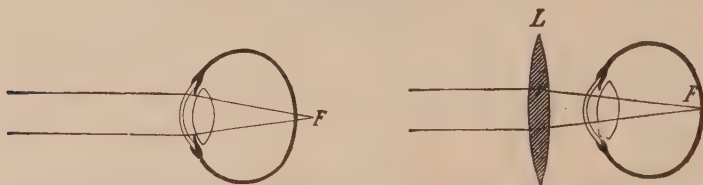


FIG. 186.—Diagrams to illustrate far sight (hypermetropia) and the use of an enlarging lens to correct it. Parallel rays focus at  $F$  back of the retina. The lens ( $L$ ) shortens the focal length causing the image to fall on the retina. (*Brubaker.*)

the formation of a clear image on the retina. It is especially annoying to students, artists, and others who must see fine print or lines. There is no cure for it, but cylindrically ground glasses are a great help.

*Infections* of the eyeball and lids are common. They are known as sore eyes, granulated eyelids, a sty, pink eye, etc. We should be very careful about neglecting an infection of the eye. Infected eyes of babies frequently caused blindness until laws were enacted

requiring doctors to treat the eyes of all babies, whether they are infected or not. The common solutions used to remove infections from eyes are a 1% solution of silver nitrate for advanced infections, a 10% solution of argyrol, or a concentrated solution of boric acid for mild infections. *Trachoma* (granulated eyelids) is a very contagious infection which is not easily cured. To avoid its spread all children suffering from sore eyes should be excluded from school until completely cured. The same is true of any cases of sores about the mouth or face. Any persistent sore may be contagious.

### OUTLINE-SUMMARY

Care of the brain and nerves: pain, sleep, digestion, headache tablets.

Care of the skin: end organs of touch, pain, heat, cold. Pimples, digestion, baths, exercise, sweat glands.

Care of the nose and mouth: senses of smell and taste. Colds, indigestion.

Care of the ear: wax, infections.

Care of the eyes: headache, eye strain, eyeglasses, cross-eyes, astigmatism, infections.

**Review Questions.**—What good does pain do? How is sleep valuable to the nervous system? How does indigestion affect the nerves? Why should we avoid headache tablets? What end organs of sense are located in the skin? How may pimples be related to digestion? Why do you suppose we advise baths and stimulation of the sweat glands? What should we do to keep the nose and throat in good condition? What should we do if we have earache? What should we do if we have pains in the eyes, or headache after prolonged study? How is far sight corrected? How is near sight corrected? What may be done for cross-eyes? How is astigmatism relieved? How may we guard against infections?

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## UNIT VI. THE CLASSIFICATION OF LIVING THINGS

**General Questions on Classification.**—Why are plants and animals classified? Why are plants and animals said to be adapted to their environment? Who devised the system of classification which we use? Upon what general principle is classification based? How is the relationship of plants and animals determined? What is von Baer's Law? What is the recapitulation theory? Why are the plants and animals of Australia different from those of the rest of the world. What are hybrids? How closely related must their parents be? What is the systematic arrangement of the naming of an animal?

### PROBLEM 1. HOW IS LIFE ADAPTED TO ITS ENVIRONMENT?

There are many different kinds of places on earth where plants and animals may live. Even in a restricted environment like a pond, living things may be found in a great variety of situations, each having essential characteristics which are different from other places in the same pond. We may realize this more fully if we consult the following table of locations and animals and plants which are adapted to them.

At the bottom far out, turtles, dragon fly nymphs.

At the bottom near shore, snails, tadpoles.

At the surface, mosquito larvæ, floating plants.

On the surface, water striders, whirligig beetles.

On plants under water, snails, algæ, worms.

On plants above water, dragon flies, spiders.

Attached, fresh water sponge, hydra, protozoans.

Swimming free, minnows, water boatmen, protozoans.

In the mud under water, fly larvæ, worms, snails.

In the millions of years that plants and animals have lived on the earth they have gradually adapted themselves to live in various situations, in various relations to other living things. As conditions

have changed, life forms have been compelled to change or disappear. The number of kinds of plants and animals living on the earth today

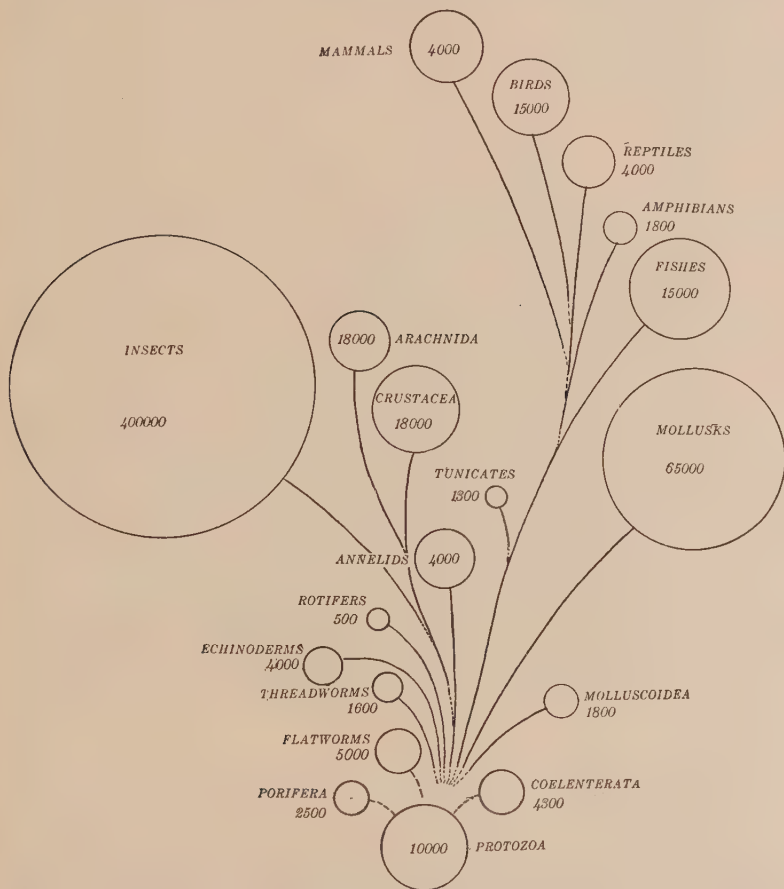


FIG. 187.—Diagram of the relationships and numbers of the groups of animals which make up the animal kingdom. (Galloway.)

is small compared to the number of those that have lived and perished. Within the recollection of man the mammoth, saber-toothed tiger, dodo, passenger pigeon, and many others have become extinct.

The fact that living things are fitted to live in the places where they are found and are not fitted to live in situations which differ greatly therefrom is known as *adaptation*. The thousands of forms which have lived and become extinct failed to keep up a perfect adaptation to their environments. In all cases this seems to have been due to the fact that their environments changed, and they failed to change accordingly.

Over 575,000 different kinds of animals and nearly as many different kinds of plants are known. There are also many kinds that have not been named and described in scientific literature. Professor Galloway has prepared a table which gives a rough estimate of the kinds of animals in each group which are still living. Note that the number of kinds of insects is by far the greatest of all. They are adapted to live in a great variety of environments.

## PROBLEM 2. WHAT IS THE BASIS OF CLASSIFICATION?

**Classification** is based on *relationship*—e.g., animals or plants which are closely related are placed together in groups. The relationship of plants and animals is determined by a knowledge of their *structure, embryology, history, geographical distribution, habits, and ability to crossbreed* with related forms. It will not be possible for us to gain a complete understanding of all of the bases for the classification of the plant and animal kingdoms, but we may consider briefly each of the kinds of information which is used. This will give us a working knowledge of how plants and animals are classified.

**The structure** of an animal refers to the shape and arrangement of its parts. Animals and plants which are closely related are very much alike in form or structure. The wading birds have long legs; the swimming birds have webbed feet. If we look at the feet of a bird, we can tell whether or not it belongs to one of these groups.

**The embryology** of an animal or plant refers to its development from the egg to the full grown type. We have seen that flowering plants have to go through the same stages of reproduction, before they can form seeds, as the ferns and mosses do. In a general way all related types have a similar embryology. This was discovered by Von Baer, a Russo-German naturalist, born in 1792, and is known



as *von Baer's Law*. We may state it briefly as follows: *Plants and animals which are closely related have similar embryological developments.* (See Fig. 189.) The principle is frequently of value in determining the relationship of a form of life which has departed widely from the general type of its group. For instance, the barnacle looks more like a mollusk in its shell than a crustacean, but its embryology is typical of all crustaceans. Therefore it is classified with the crustaceans, and not with the mollusks.



FIG. 188.—A fossil cup coral. A type of life which is now extinct.

**The geological history** of a plant or animal is the record which its ancestors have left in the stratified rocks. Many of the animals which died in the past left records of their structure in the form of foot prints, shells, bones, teeth, etc. (Fig. 188). Frequently we can trace a line of development of life back to an ancestor which was considerably different from the present type. If two lines of modern life can be traced to a common type of ancestral life, we know the relationship of the two types.

The geological history and the embryology of a group of animals should check, so that each confirms the other. Hackel and others used this system of checking to determine the ancestry of living

forms. It is called the *theory of recapitulation*, because the stages of embryological development repeat or "recapitulate" the geological



FIG. 189.—Three stages in the development of the fish, salamander, tortoise, and chick to show their similarity. (Häckel.)

history which is learned from fossils. The history is never perfectly repeated in the embryology. There are minor omissions, addi-

tions, and modifications of the structures of the embryos. The theory is really a modification of Von Baer's law.

In the illustration (Fig. 189) the early stages of the four embryos are shown to be very much alike, but as they develop they diverge, each becoming a different type of life. Note that they all have gill arches at first. Also that their bodies are segmented. In the second series the fish develops internal gills, the salamander develops external gills, and the turtle and bird have theirs reduced.

**Geographical Distribution.**—The native mammals of Australia are all members of the orders *Monotremata* and *Marsupialia*. This is believed to be due to the fact that the continent has been sepa-



FIG. 190.—The duckbill of Australia. This mammal has a skeleton which resembles that of a reptile in many ways. It lives in the water like a muskrat, and lays eggs like a reptile. It is found only in Australia. (Folsom.)

rated from the other land masses for a long time, and these were the only types of mammals living on the earth when the separation took place. The monotremes (duckbills) (Fig. 190) are found nowhere else, and the marsupials (kangaroos, etc.) are represented elsewhere by one group, the opossums of North and South America. Many animals from other continents thrive in Australia now that man has introduced them.

Wallace, the English naturalist, showed that insects which are found on coastal islands have come from the mainland. Even if they differ from the type which remains on the continent, we must classify them close together because of their relationship. We also

believe that the marsupials of Australia are all related, because they have had no contact with other marsupials for ages, and it is unlikely that any have gone there from some other continent.

**Habits.**—Animals which are closely related have similar habits. Lions, tigers, panthers, leopards, and the domestic cat are closely related. They all catch prey in a similar way,—by stealth; but not in exactly the same way. Each form behaves according to the general habits of the group but has its own characteristics,—*e.g.*, panthers and leopards commonly climb trees, but lions do not.

**Crossbreeding.**—The test of crossbreeding is applied to forms that are closely related. The lion and the tiger are more closely



FIG. 191.—Squashes and pumpkins. Produced by hybridization. Do you know the name of each kind represented in the illustration?

related than the domestic cat and the tiger, for the lion and the tiger will crossbreed, but the tiger and the domestic cat can not. The offspring of such crossbreeding is known as a *hybrid*. If the parents are not closely related the offspring will not breed and so the new type can not perpetuate itself. Dogs and wolves often crossbreed. In this case the young are able to breed, and the hybrids may be perpetuated. The mule is a cross between the horse and the donkey, but mules never bring forth colts. It is believed that the wolf and

the dog are very closely related, and that the donkey and horse are not so closely related. The crossing of plants and the production of hybrids is the chief method by which the multitude of domestic plant forms have been produced from their wild ancestors. (See Fig. 191.) (See p. 166.)

**Taxonomy** is the classification of plants and animals. When we find a large number of individuals so nearly alike that they are practically alike, they are put in one group called a *species*. It is the unit of classification. All lions belong to the species *leo*, all tigers to the species *bengalis*, all domestic cats to the species *domestica*. While all domestic cats are very much alike, they, however, are of certain types. Some are black, some white, some long haired, some short haired, etc. These are grouped in subdivisions called *races* or *varieties*. The varieties of a species are usually able to crossbreed readily, and are able to produce offspring in the second generation.

**Species** which are closely related, such as the cat, lion, tiger, and puma fall naturally into a larger group called a *genus* (pl. *genera*). A genus is composed of closely related species. When an animal is named it always bears two names—the *generic* and *specific*. The generic name is always spelled with a capital letter and the specific with a small letter even if it is derived from a proper noun. The scientific name for the lion is *Felis leo*; the tiger *Felis bengalis*; the Canadian lynx is *Lynx canadensis*.

**Genera** fall naturally into larger groups called *families*. All cat-like animals belong to the cat family, bear-like animals to the bear family, and wolf-like animals to the wolf family which includes the dogs.

**Families** are arranged in *orders*. As we arrive at the larger groups the system becomes less natural and more artificial because relationships can not always be determined accurately. All flesh-eating animals—cats, bears, dogs, seals, etc.—are placed in the order *Carnivora*.

**Orders** are arranged in *classes*. Fur-bearing animals possess mammary glands (milk glands) for nursing their young. They belong to the class *Mammalia*.



**Classes** are arranged in *phyla* (Sing. *phylum*). All animals having a backbone, such as fishes, frogs, lizards, birds, and mammals are put in the sub-phylum *Vertebrata* which is in the phylum *Chordata*. In this case a sub-phylum is made. We may have *sub-* or *super-*phyla, classes, orders, and genera.

The **phyla** are the largest divisions of the plant and animal *kingdoms*. Thus we have the following systematic arrangement: *variety, species, genus, family, order, class, phylum, kingdom*.



FIG. 192.—Linnaeus, the originator of our system of classification (1707-1778)  
(Gager.)

**Nomenclature** is the naming of plants and animals. Each plant and animal known to science is named in accordance with a plan arranged by Linnaeus (1707-1778), a Swedish botanist. His system has been revised from time to time but its essential principles remain unchanged.

The scientist who first describes a plant or animal has the right to name it, and it must be known by that name forever afterward. The names all have Latin endings. This is not necessary but was started by Linnæus and has certain conveniences which cause it to be continued.

### PROBLEM 3. HOW ARE PLANTS CLASSIFIED?

Perhaps it is stretching the use of the word to call this study a problem today. It is our inclination to accept that which is tabulated for us. There is very little new work on classification. So far as we are concerned, the problem has been solved, except for a very few unknown plants.

There was a time when the classification of plants was the chief interest of the botanist, but so many new and valuable interests have come into the study of plants that classification is now of secondary importance; however we must classify all plants in our mind as we deal with them. We should always know that the plant under consideration is an alga, a fern, or whatever it may be. All of the names which appear in the tables should not be learned. They are, for the most part, there for reference. For our purposes it is more important to learn how plants and animals are grouped according to relationship, and which ones bear close relationship, than to learn the technical terms used in classification. The illustrations of both plants and animals should be carefully observed, and specimens of as many as are available should be shown to the classes.

### THE PLANT KINGDOM

**PHYLUM I. THALLOPHYTA:** plants without true roots, stems, leaves, or flowers. Reproduce by spores.

**SUB-PHYLUM 1. ALGÆ:** plants possessing chlorophyll.

**SUB-PHYLUM 2. FUNGI:** plants without chlorophyll.

This is the simplest group of plants. They live largely in the water and have no fibrovascular tissue, hence, each cell is largely independent of the others in food getting but not entirely so in all



FIG. 193.—Representatives of four groups of spore producing plants. A, a red alga; B, a mushroom belonging to the fungi; C, moss plants; D, a fern plant.



FIG. 194.—Representatives of four groups of seed producing plants. A, a cedar tree; B, a palm; C, tulips (Monocotyledon); D, a cosmos (Dicotyledon).

cases. *Pond scums* and *green slime* belong to the algæ. *Bacteria*, *yeasts*, *molds*, and *mushrooms* belong to the fungi.

PHYLUM II. BRYOPHYTA: green plants without true roots, stems, leaves or flowers; reproducing by spores with alternation of generations. The *liverworts* and *mosses* constitute the two classes.

PHYLUM III. PTERIDOPHYTA: green plants having roots, stems and leaves but no flowers; reproducing by spores with alternation of generations. The *ferns*, *horsetails*, and *club mosses* constitute the three classes.

PHYLUM IV. SPERMATOPHYTA: green plants having roots, stems, leaves, and flowers or cones. Reproducing by spores with alternation of generations and seed.

SUB-PHYLUM 1. GYMNOSPERMÆ: cone bearing plants, usually evergreens such as *pine*, *spruce*, *hemlock*, *cedar*, *cypress*.

SUB-PHYLUM 2. ANGIOSPERMÆ: flowering plants. They are divided into two classes,—MONOCOTYLEDONS and DICOTYLEDONS. All plants which have leaves, stems, roots, and flowers may be assigned to one or the other of the two groups according to their structure. If you think of the stem and leaves of the corn stalk, or of a canna lily which are without rings, you will note that they are more alike than either is like the geranium which has rings. The veins in the leaves of lilies run parallel to each other, but those of plants like the pea or geranium run through the blade of the leaf in the form of a network. The petals, and other parts, of the flowers of lilies are arranged in groups of three; while the petals, and other parts, of geranium and pea flowers are arranged in groups of four or five, but never three. Even the seeds are different. When the seeds of corn and lilies sprout only one leaf emerges from the seed coats, but when the seeds of plants of the other type germinate there are two seed leaves. Thus we see that the leaves, stems, flowers, and seeds of these two groups of plants are all different. Those plants with one seed leaf are called *monocotyledons* (mo-nō-kot-e-le'dun) which means one seed leaf; and those plants which have two leaves in the seed are called *dicotyledons* (dī-kot-e-le'dun) which means two seed leaves. All of the above-mentioned features are shown in figure 195. Study it carefully.



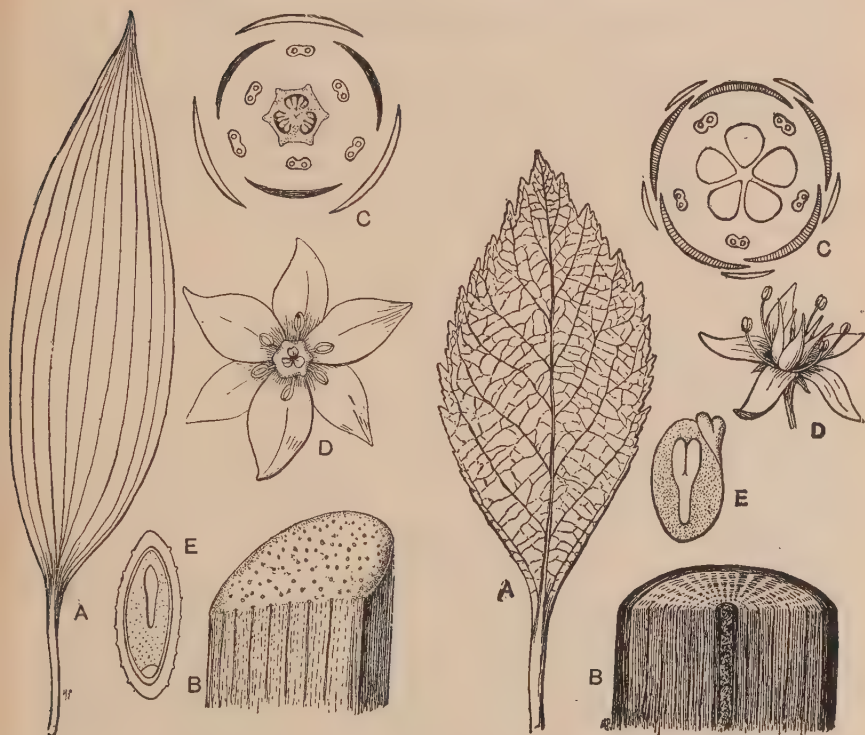


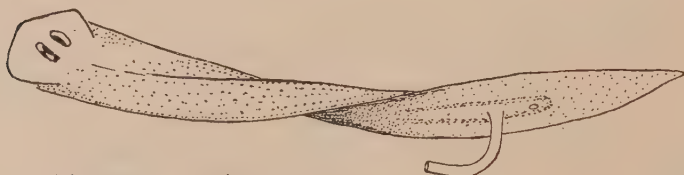
FIG. 195.—Drawings to show the differences between the stems, leaves, flowers, and seeds of monocotyledons and dicotyledons. (*Gager.*)

Fill out the table for your notebook setting forth the differences between the parts which bear the same letters. In each case *C* is a cross section of a flower showing sepals, petals, stamens, and ovary.

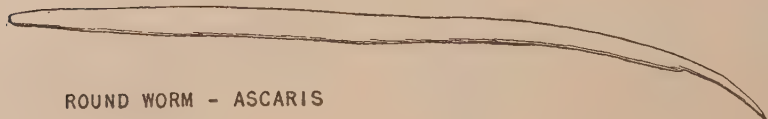
|             | Monocot | Dicot |
|-------------|---------|-------|
| Stem.....   |         |       |
| Leaf.....   |         |       |
| Flower..... |         |       |
| Seed.....   |         |       |

**PROBLEM 4. HOW ARE ANIMALS CLASSIFIED?**

We have seen that we are able to place all plants in four phyla. The classification of animals is much more diverse. We must use ten phyla for the most condensed arrangement that is acceptable. Plants are arranged fundamentally on their anatomy and methods of reproduction, but animals have no such complicated reproductive processes. Therefore, we are compelled to rely more on their



FLAT WORM - PLANARIA



ROUND WORM - ASCARIS



SEGMENTED WORM - EARTHWORM

FIG. 196.—Three types of worms. Note that they are named after their chief characteristic in each case.

anatomy; however, the development of animal embryos is sufficiently diverse in various groups, and constant within any one group, to be of great value.

**THE ANIMAL KINGDOM**

**PHYLUM I. PROTOZOA:** single-celled animals.

**Class 1. RHIZOPODA:** no definite cell wall, form pseudopodia.  
Example: *Ameba*.

**Class 2. MASTIGOPHORA:** possess flagella and often chlorophyll.  
Example: *Euglena*.

**Class 3. INFUSORIA:** possess cilia or tentacles. Examples:  
*Paramecium*, *Vorticella*.

**Class 4. SPOROZOA:** parasitic forms, reproducing by swarm spores. Example: *Plasmodium malaria*.

**PHYLUM II. PORIFERA:** *sponges*.



FIG. 197.—Four types of molluscs. A, a cephalopod (octopus); B, a pelecypod (clam); C, an amphineuran (chiton); D, a gastropod (snail). Each is displayed in a natural position in the water.

**PHYLUM III. CŒLENTERATA:** radiate animals (parts arranged around a center like the spokes of a wheel) without anus or body cavity. Examples: *hydra*, *jellyfish*, *corals*, *anemones*.

**PHYLUM IV. ECHINODERMATA:** radiate animals with complete alimentary canal and body cavity. There are five classes,—*sea-lilies*, *sea-urchins*, *brittle stars*, *starfish*, *sea-cucumbers*.

**PHYLUM V. PLATYHELMINTHES:** unsegmented flat worms. There are three classes,—*planarians*, *tapeworms*, *flukes*. The planarians are free living; the others are parasitic.

PHYLUM VI. NEMATHELMINTHES: unsegmented round worms. Examples: *intestinal worms*, *vinegar eels*, *trichina*, *ascaris*.

PHYLUM VII. ANNULATA: segmented worms. Examples: *earthworm*, *tube-worm*, *leech*.

PHYLUM VIII. MOLLUSCA: unsegmented, soft bodied animals with an internal or external shell.

Class 1. GASTROPODA: univalves,—*snails* and *slugs*.

Class 2. PELECYPODA: bivalves,—*clams* and *oysters*.

Class 3. AMPHINEURA: many-valved,—*chitons*.

Class 4. CEPHALOPODA: with many tentacles and eyes similar to those of the vertebrates. Examples: *squid*, *cuttlefish*, *octopus*, *nautilus*.

PHYLUM IX. ARTHROPODA: animals with jointed legs, an external skeleton, and ventral nervous system.

Class 1. ONYCHOPHORA: worm-like, breathe with tracheæ. Example: *peripatus*. Very rare, found only in the tropics.

Class 2. MYRIAPODA: long bodies, many legs, breathe with tracheæ. Examples: *centipeds* and *millipeds*.

Class 3. CRUSTACEA: breathe with gills or with no special respiratory structures. Examples: *pill-bugs*, *barnacles*, *crayfish*, *crabs*, *lobsters*, *shrimps*, *cyclops*.

Class 4. ARACHNIDA: eight legs, breathe with lung-books. Examples: *spiders*, *scorpions*, *ticks*, *mites*, *horseshoe crab*.

Class 5. INSECTA: six legs, breathe with tracheæ. Examples: *insects*.

We have given considerable attention to insects in the studies on the grasshopper and bee. Because of their great importance we will include in this tabulation some of the important orders. We may divide all insects into two groups according to the way the young develop from the egg. We have mentioned this before in the study on the grasshopper. If they develop directly they are said to have a *direct metamorphosis*, but if they have a larval period and "rest" in the form of a pupa or chrysalis before becoming adult, they are said to have an *indirect metamorphosis*.

Many orders of insects are named after the form of their wings. The Greek for wing is *pteron*, and it will be noticed that this word appears in many names of orders.

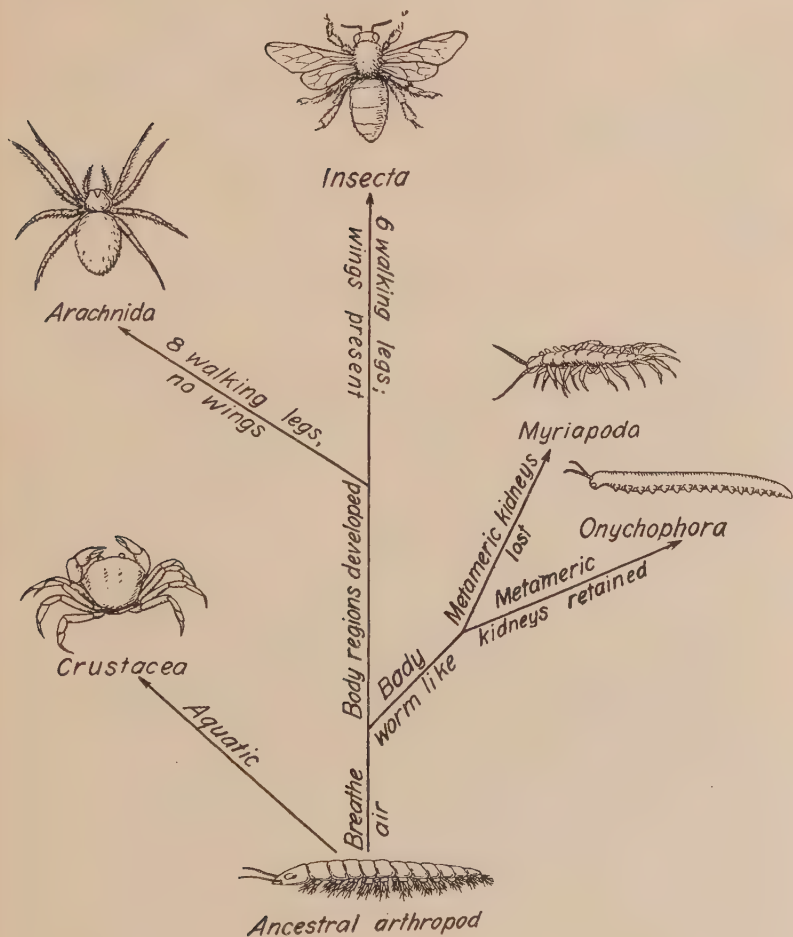


FIG. 198.—A scheme to show how the five classes of arthropods have developed from their common ancestor. (After Pearse, *General Zoology*; Henry Holt & Co.)



| ORDER                             | PRONUNCIATION | MEANING             | EXAMPLE     |
|-----------------------------------|---------------|---------------------|-------------|
| INSECTS WITH DIRECT METAMORPHOSIS |               |                     |             |
| Aptera.....                       | ăp'tě-ră      | no wings            | fish moth   |
| Orthoptera.....                   | ôr-thôp'tě-ră | straight wings      | grasshopper |
| Odonata.....                      | ô-dôn-ă'tă    | toothed (mandibles) | dragon fly  |
| Hemiptera.....                    | hē-mĭp'tě-ră  | half winged         | bug         |
| Ephemera.....                     | ê-fēm-ěr'i-dă | short-lived         | may-fly     |
| Plecoptera.....                   | plĕk-ôp'tě-ră | plaited wings       | stone fly   |
| Neuroptera.....                   | nû-rôp'tě-ră  | nerve-veined wings  | lace-wing   |

## INSECTS WITH INDIRECT METAMORPHOSIS

|                  |                 |               |            |
|------------------|-----------------|---------------|------------|
| Trichoptera..... | trĭk-ôp'tě-ră   | hair winged   | caddis fly |
| Lepidoptera..... | lĕp-ĭ-dôp'tě-ră | scale winged  | butterfly  |
| Diptera.....     | dĭp'tě-ră       | two winged    | mosquito   |
| Coleoptera.....  | kôl-ê-ôp'tě-ră  | sheath winged | beetle     |
| Hymenoptera..... | hĭ-mĕn-ôp'tě-ră | united wings  | bee        |

PHYLUM X. CHORDATA: animals with a notochord or vertebral column.

SUB-PHYLUM—VERTEBRATA: animals with a vertebral column, dorsal nervous system and gills in embryo or adult.

**Class 1.** PISCES: breathe with gills, body covered with mucus, often with scales, cold blooded. Example: *fish*.

Fishes are so ancient and so different that we should consider the five great divisions into which the group may be divided.

**1. The ostracoderms** (Gr. *osiracho* = shell + *derma* = skin) were heavily armoured, fish-like creatures which lived in the seas in ancient times. They perished before the close of the carboniferous period, which was many millions of years ago.

**2. The ganoids** (Gr. *ganin* = brightness) are named from the shining *ganoin* which covers their scales. It is a very durable and somewhat flexible material which forms a heavy coat of armor on some forms. They are an ancient group with few modern representatives, among which may be mentioned, the fresh water dogfish, gar pike, alligator gar, sturgeon, and spoonbill which are found in the waters of North America. Ganoids are sometimes placed with the teleostomes, but because of their ancient origin and simple type, they should be separated.

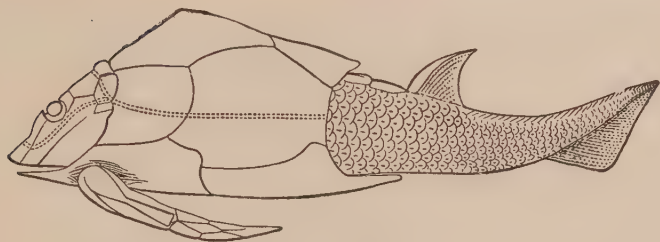


FIG. 199.—Restoration of an ostracoderm. (*Norton, Elements of Geology. Ginn & Company.*)

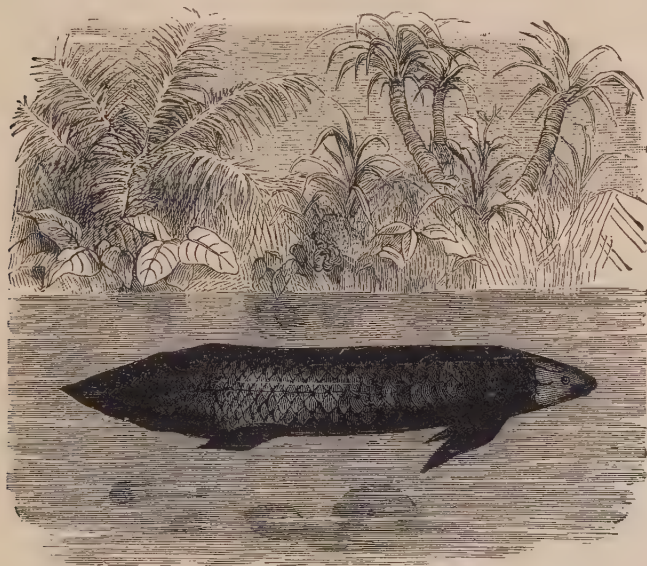


FIG. 200.—The Australian lung fish. (*From Basket, The Story of the Fishes. D. Appleton & Co., New York.*)

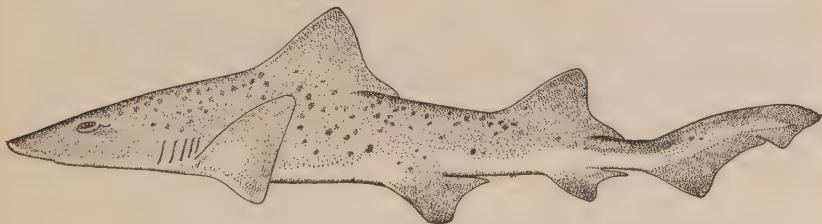


FIG. 201.—The dogfish shark. (*Evermann and Radcliffe.*)

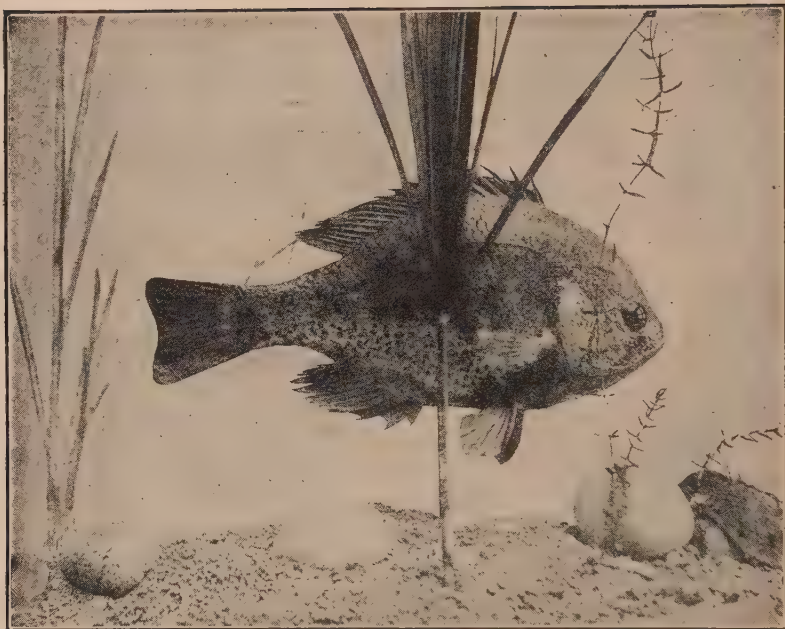


FIG. 202.—A bluegill, one of the bony fishes.



FIG. 203.—Amphibians—the leopard frog, and two tiger salamanders.  
See also Figs. 151 and 152.

3. **The dipnoans** (Gr. *di* = two + *pneo* = to breathe) were the lung fishes and were closely related to the ancestors of the amphibians and ganoids. They are nearly all extinct; but three genera remaining; one each in Africa, South America, and Australia.

4. **The elasmobranchs** (Gr. *elamos* = plate + *branchi* = gills) are the sharks and rays. With the exception of one species which



FIG. 204.—Typical reptiles representing four classes—A, the chameleon in its terrifying attitude, a member of the lizard group; B, the water snake in an attitude of fear; C, the spotted turtle at rest; D, an alligator in great anger and excitement. The picture of the alligator is from a mounted specimen; the others are from life.

lives in Lake Nicaragua, they are all marine; and although quite numerous, they are of little economic importance except as destroyers of other fish. Some are used as food.

5. **The teleostomes** (Gr. *teleos* = complete + *stoma* = mouth) are the bony fishes. As their name indicates, they have a complete lower jaw. Their gills are covered with an *operculum* (L. a lid), and their bodies are usually protected with scales. This group con-



tains ninety-five per cent of all living fish, and its members are masters of both the salt and fresh waters of the earth to-day.

**Class 2. AMPHIBIA:** breathe with gills, lungs, or through the skin; body covered with mucus or dry, never with scales; cold blooded. Examples: *newts, salamanders, frogs, toads.*

**Class 3. REPTILIA:** breathe with lungs, body covered with scales, cold blooded. Examples: *lizards, alligators, snakes, turtles.*

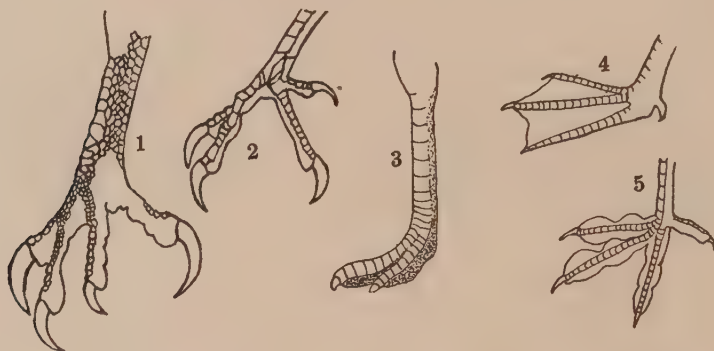


FIG. 205.—The feet of five birds. 1, hawk; 2, woodpecker; 3, ostrich; 4, duck; 5, grebe. The structure of bird's feet and legs is the most reliable consideration in determining to what class they belong. (Holmes.)

**Class 4. AVES:** breathe with lungs, body covered with feathers, warm blooded. Example: *birds.*

As is the case with the insects, the birds are of so many kinds that we can not give all of the orders here. We may mention some of those which are of the greatest importance to us in the table which follows.

#### ORDERS OF BIRDS

#### EXAMPLES

|                  |                                              |
|------------------|----------------------------------------------|
| Pygopodes.....   | (diving birds) grebes, auks.                 |
| Longipennes..... | (long-winged swimmers) gulls, terns.         |
| Anseres.....     | (heavy-bodied swimmers) ducks, geese, swans. |
| Herodiones.....  | (wading birds) herons, bitterns, storks.     |
| Paludicolæ.....  | (marsh birds) cranes, rails, coots.          |
| Limicolæ.....    | (shore birds) snipes, plovers, stilts.       |
| Gallinæ.....     | (gilled birds) chicken, quail, turkey.       |
| Columbæ.....     | doves and pigeons.                           |
| Coccyges.....    | (peculiar birds) cuckoos, kingfishers.       |





FIG. 206.—The brown thrasher, a representative of the birds.



FIG. 207.—The raccoon, a representative of the mammals. This specimen is shown balancing himself with his tail as he is coming down to the water.

## ORDERS OF BIRDS -

## EXAMPLES

|                  |                                                                                                                                                                                                                                                                                               |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pici.....        | woodpeckers and sapsuckers.                                                                                                                                                                                                                                                                   |
| Macrochires..... | swifts, nighthawks, humming-birds.                                                                                                                                                                                                                                                            |
| Striges.....     | (night birds of prey) owls.                                                                                                                                                                                                                                                                   |
| Raptores.....    | (day birds of prey) hawks, vultures.                                                                                                                                                                                                                                                          |
| Passeres.....    | (perching and singing birds) sparrows, robin, phœbe,<br>kingbird, larks, crows, jays, orioles, blackbirds,<br>finches, tanagers, swallows, waxwings, shrikes,<br>vireos, warblers, wrens, catbird, mocking-bird,<br>thrasher, creepers, titmice, nuthatches, kinglets,<br>thrushes, bluebird. |

**Class 5. MAMMALIA:** breathe with lungs, body covered with hair, warm blooded, possess mammary glands. Example: *mammals*.

## ORDERS OF MAMMALS

## EXAMPLES

|                  |                           |
|------------------|---------------------------|
| Monotremes.....  | Duckbill, spiny anteater. |
| Marsupials.....  | Kangaroo, opossum.        |
| Edentata.....    | Anteater, armadillo.      |
| Rodentia.....    | Squirrel, rat, beaver.    |
| Cetacea.....     | Whale, porpoise.          |
| Ungulata.....    | Horse, pig, deer, cow.    |
| Insectivora..... | Mole, shrew.              |
| Cheiroptera..... | Bats.                     |
| Carnivora.....   | Seal, bear, cat, dog.     |
| Primates.....    | Monkey, ape, man.         |

**Suggestion.**—It may be profitable to go to a botanical garden or a museum to observe examples of the phyla and classes mentioned in these studies.

## OUTLINE-SUMMARY FOR UNIT VI

Adaptation as illustrated in a pond.

Estimated number of animals and plants.

Classification: structure, embryology, history, geographical distribution, habits, ability to crossbreed.

Nomenclature: Linnæus system.

Importance of classification in botany.

The classification of the plant kingdom.

Comparison of classification of plants and animals.

The classification of the animal kingdom.

**Review Questions on Unit VI.**—Name some situations in a pond and state what living things may be found there. What

happens to plants or animals if they fail to adapt themselves to new situations? Are there many extinct creatures? Why did they become extinct? How great is the number of living animals? On what six considerations are plants and animals classified? Do not try to learn the tables of classification. They are for reference.

#### General References

Pearse, *General Zoology*, Henry Holt & Co.  
Crary, *Field Zoology*, P. Blakiston's Son & Co.  
Linville and Kelly, *General Zoology*, Ginn & Co.  
Cowles and Coulter, *Spring Flora*, American Book Co.  
*The New Nature Library*, Doubleday Page and Co.

#### Advanced References (Technical)

Grey, *Manual of Botany*, American Book Co.  
Jordan, *Manual of the Vertebrates*, A. C. McClurg & Co.  
Pratt, *Vertebrates of the U. S.*, P. Blakiston's Son & Co.  
Folsom, *Entomology*, P. Blakiston's Son & Co.

## UNIT VII. THE BIOLOGY OF HEALTH AND DISEASE

Health is our greatest blessing and the lack of it is our greatest misfortune. No one can be happy who is in continued poor health. If we could solve the problem of health, we would be going a long ways toward solving the problem of perpetual happiness.

We have not completely solved the problem of how to have good health, but we have solved the other side of the question. We know the cause of disease, and how to prevent it. When we have mastered the information of the following problems, we may know how nearly all of our contagious diseases may be eliminated. If we can get people to completely coöperate, we can totally eliminate all of these diseases. The control which we have over them now is measured exactly by the knowledge which we have, and the spirit of coöperation which exists among us.

## PROBLEM 1. HOW DO FUNGUS PLANTS LIVE?

**General Questions.**—What is the relative importance of fungi? Are all fungi parasites? What are the five most important groups of fungi? Into what three groups are bacteria divided? How do bacteria reproduce? How do yeasts reproduce?

The diseases of plants, animals, and mankind which are contagious are produced by bacteria and protozoans, with but few exceptions. Those which are caused by protozoans are few. If we wish to gain a full understanding of the nature of these disease producers, we should make a thorough study of fungi, the group of plants to which they belong. Therefore, we shall concern ourselves, in this problem, with the important facts of the lives of fungi.

The fungus plants which have been named number 66,700 species. This is over one-fourth of all known species of plants. They have no roots, stems, or leaves and resemble the algæ in many details, having in all probability, descended from them. They differ from the algæ in that their spore bearing structures in the highest forms are more complex, and in that they have no chlorophyll.

The absence of chlorophyll is their most distinguishing characteristic. It causes them to be dependent upon food-stuffs which have been prepared by the green plants and animals. They, therefore, play the same general rôle in nature's food cycle which is played by the animal kingdom. Because of this dependence they are compelled to live either as *parasites* (living on living things), or *saprophytes* (living on dead things), or in some cases they are either saprophytic or parasitic in which case they may begin their life on a living thing and continue to live upon it after they have caused its death.

In this study it will be necessary to confine our attention to three types of fungi. Others will be studied in following lessons.

**Bacteria.**—For our purposes this division may be classified according to their shape into three groups, which are the *coccus* group which is composed of spherical forms, the *bacillus* group which comprises



the rod-shaped species, and the *spirillum* group composed of spiral-shaped bacteria. (See Fig. 209.)

Recently, there has been a tendency among some bacteriologists to classify the spiral-shaped bacteria among the protozoans, but this is an error. The spirilla are plants by every test which we can make. They have none of the characteristics of animals, except movement; and in this particular, they do not move any more than the bacilli do.

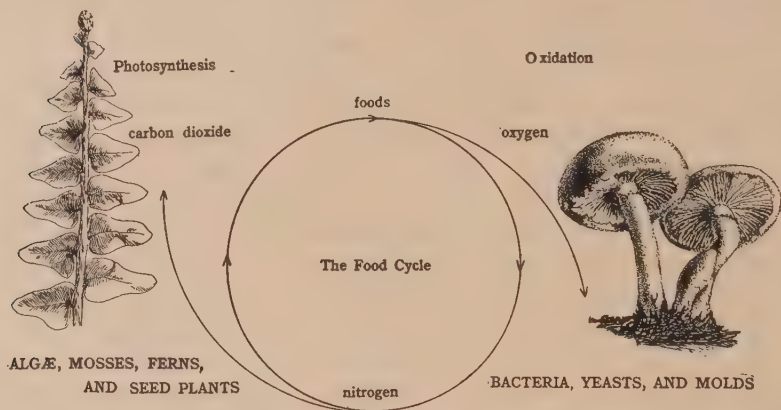


FIG. 208.—The food cycle between green plants and fungus plants. Compare this figure with Figs. 21 and 65.

**Reproduction.**—In their methods of reproduction bacteria are like the blue-green algæ. Each individual is a single cell and on attaining full size, divides through the center and becomes two individuals. Many forms of bacteria produce resting spores to tide them over an unfavorable period of drought or other condition which prevents growth. When in the spore condition they can withstand great extremes of dryness, heat, and cold. Fortunately, few of the forms causing human diseases produce spores, and, hence, they are easily killed.

Bacteria are everywhere. We eat them, drink them, and breathe them in countless millions; yet they ordinarily do us no harm. Milk, buttermilk, cheese, and sauerkraut swarm with them. They are present on the surface of most all of our foods and cause decay if

the moisture and temperature conditions are suited to their growth. All spoilage of food is due to bacteria and other fungi.

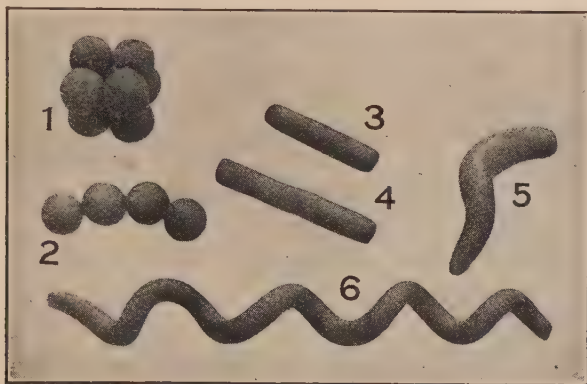


FIG. 209.—Types of bacteria which cause disease in man.

| Coccus group            | Bacillus group        | Spirillum group |
|-------------------------|-----------------------|-----------------|
| 1, staphylococcus;      | 3, influenza (?);     | 5, cholera;     |
| 2, streptococcus;       | 4, tuberculosis;      | 6, syphilis.    |
| Form pus and are asso-  | Cause contagious dis- |                 |
| ciated with other forms | eases.                |                 |
| in pneumonia.           |                       |                 |

From a photograph of wax models, made by the author. Can the class prepare models of this type for all of the harmful bacteria? See illustrations in texts in bacteriology, and make the models to a convenient scale. Mount them in insect cases or on plates and save them.

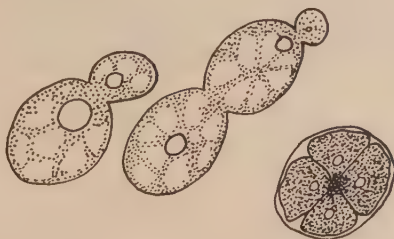


FIG. 210.—Yeast plants multiplying by *budding* on the left, and multiplying by *spore formation* on the right. Note that there are four spores within the old cell wall.

**Yeasts** are fungi of uncertain relationships in regard to their classification. They multiply by budding, as shown in the illustration (Fig. 210). They are much larger than bacteria and have a large,

clear nucleus. At certain times they form spores in groups of two, three, or four. They live principally in sugar solutions. They change sugar into alcohol and carbon dioxide.

In bread making the carbon dioxide which is produced by the yeast fills the dough with many small spaces. When it is baked the alcohol formed is driven off, the yeast is killed, and the dough hardens leaving the bread spongy.

In spite of the great benefit derived from yeasts in bread making, they have been one of the greatest curses of mankind. Nearly every

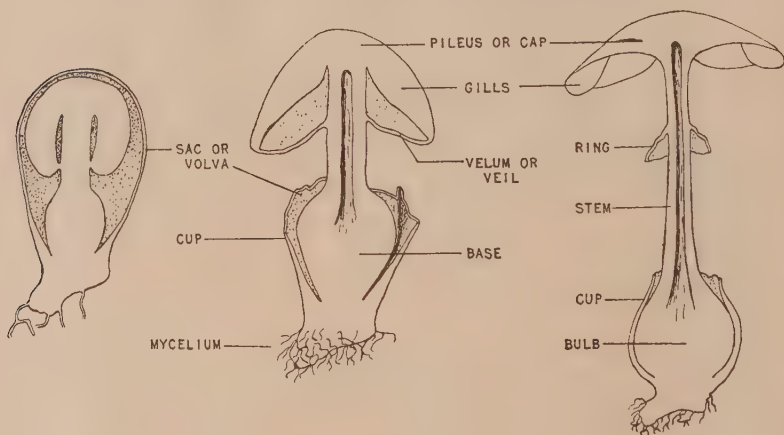


FIG. 211.—Diagram of the death cup (*Amanita phalloides*) to show its characteristics by which it may be known.

people has had its intoxicating drink made by the action of yeasts on grain or fruit juices. The production of alcohol by yeasts may yet prove to be a blessing. When the supply of petroleum is exhausted we may run our automobiles by alcohol derived from the action of yeast on simple sugars which may be made from wood pulp, corn stalks, and other plant products which are composed chiefly of cellulose. Alcohol is now used extensively in industry.

**Mushrooms** abound in fields and woods from spring to winter, but they are most abundant in the fall. They are multiplied by spores which are easily scattered by the wind. For this reason the same species are usually found on all of the continents. Most

localities should yield about 1,000 varieties. *Nine of these are deadly poisonous*, all of which belong to the genus *Amanita*. McIlvane lists 735 which are good to eat. Fortunately, it is possible to identify the amanitas by their *white spores*, the *presence of a ring*, and a *cup or swelling at the base*. Furthermore, the amanitas usually grow in



FIG. 212.—The shaggy-mane mushroom (*Coprinus comatus*), the finest and most beautiful of the wild mushrooms. When ripe it turns black and melts away to an inky fluid filled with black spores. All mushrooms which do this are called "ink caps" They are all edible when young.

the woods. *Beware of mushrooms with white spores.* All others are probably good if they are palatable.

Mushrooms contain a great amount of water but are very rich in protein food, and are a better food than meat because they are more easily digested; but because of an inability on the part of the public to distinguish the amanitas, and, hence, a fear of all forms; tons of this most excellent food go to waste in every locality each year. On

your field trips learn to know the poisonous ones, and gather the others. (See Figs. 211 and 212.)

The mushroom is the fruiting structure of the plant and is called the *sporophore* (spore bearer). In the soil many thread-like filaments may be found. They are the food-getting part of the plant and are called the *mycelium*. A single thread is called a *hypha*. When a sporophore is young it is rounded in form and is called a *button*. It is entirely enclosed in a membrane called the *volva* or *sac*. As the button grows it is pushed upward by the lengthening of its stem, and the volva is ruptured. The part remaining about the base of the stem is called the *cup*. The sporophore is composed of a *stem*, a *pileus* or *cap*, and *gills* or some other structures which bear the spores. *Warts* are patches of the volva remaining on the upper surface of the cap. The *velum* or *veil* is a membrane which attaches the edge of the cap to the stem and is broken when it expands. In the *amanitas* it leaves a *ring* around the stem. All mushrooms do not contain all of the structures mentioned, but a knowledge of the terms is necessary in identifying and classifying fungi.

Do not let the wild mushrooms go to waste in your community. Have a report given on the raising of domestic mushrooms for market. Write to the Department of Agriculture, Washington, D. C., for a bulletin giving complete information on this profitable industry.

Not all mushrooms, by any means, are beneficial. Some live on the trunks of trees, and finally destroy them. Such trees show *brackets* or *shelves* on their bark. If diseased trees are not removed the spores produced in the brackets will affect other trees which may have a wound, due to a broken limb or an insect injury, through which the spores may enter and grow.

All diseased trees should be cut down and removed at once. It is usually useless to try to save them by tree surgery. Make a census of your block in the city. How many trees should be removed? Can you do anything to better this condition?

**Review Questions.**—Are the fungus plants numerous? How are they like the algæ. How do they differ from all green plants? What are parasites? What are saprophytes? Describe each of the three types of bacteria. How do bacteria reproduce? How do yeasts multiply? For what are yeasts used? Where do



mushrooms grow? Are there many different kinds? Describe a typical mushroom naming the parts. How are they related to trees in an economic sense?

## PROBLEM 2. HOW ARE FUNGI RELATED TO PLANT DISEASES?

**General Questions.**—Are plant diseases common? About how many are there? About how much damage do they do? How did potato blight cause famine in Ireland? How was the famine checked? What is the life history of potato blight?

There are about 250 common diseases of domestic plants and forest trees which are caused by fungi. Duggar lists 24 diseases of the apple alone. They constitute fully as great a problem to the farmer, gardener, and orchardist as do soils, climate, pure seed, or cultivation.

The annual losses of the farmers of the United States from fungus diseases amount to over half a billion dollars. The loss from potato blight alone amounts to \$36,000,000.

If we can find ways of reducing this damage and loss, we will have rendered a service to our fellows, and will have added greatly to the economic values of agriculture. Much is being done to fight plant diseases. We propose to study some of these diseases as types and to consider the methods which have been devised for their control.

**Potato Blight.**—We will consider potato blight (*Phytophthora infestans*) as a type of fungus disease. It had its origin in South America and followed the potato to Europe and North America. It attacks the potato vines rather suddenly about the latter part of July, and in a short time they wither and die. For the past century the farmers of Ireland have lived mostly on the potato. When the blight swept over the island in 1845-46 it caused one of the most dreadful famines the world has ever witnessed. Some idea of the catastrophe may be gained by reading the following from Fitzmaurice and Thursfield in Larned's *History for Ready Reference*.

"The harvest of 1845 promised to be the richest gathered for many years. Suddenly, in one short month, in one week it might be said, the withering breath of a simoon seemed to sweep the land, blasting all in its path. I myself saw whole tracts of potato growth changed in one night from smiling luxuriance to a shriveled and

blackened waste. A shout of alarm arose. But the buoyant nature of the Celtic peasant did not yet give way. The crop was so profuse that it was expected the healthy portion would reach an average result. Winter revealed the alarming fact that the tubers had rotted in pit and storehouse. Nevertheless the farmers, like hapless men who double their stakes to recover losses, made only more strenuous exertions to till a larger breadth in 1846. Although already feeling the pinch of sore distress, if not actual famine, they worked as if for dear life; they begged and borrowed on any terms the means whereby to crop the land once more. The pawn offices were choked with the humble finery that had shone at the village dance or the christening feast; the banks and money-lenders were besieged with appeals for credit. Meals were stinted, backs were bared. Anything, anything to tide over the interval to the harvest of "Forty-six".

It was this harvest of Forty-six that sealed their doom. Not partially but completely, utterly, hopelessly, it perished. As in the previous year, all promised brightly up to the close of July. Then, suddenly, in a night, whole areas were blighted; and this time, alas! no portion of the crop escaped. A cry of agony and despair went up all over the land. The last desperate stake for life had been played and all was lost. The doomed people realized but too well what was before them. Last year's premonitory sufferings had exhausted them and now?—they must die.

"We raised a public subscription, and employed two men with horse and cart to go around each day and gather up the dead. One by one they were taken to a great pit at Ardnabrahair Abbey and dropped through the hinged bottom of a trap-coffin into a common grave below. In the remoter rural districts even this rude sepulcher was impossible. In the field and by the ditchside the victims lay as they fell, till some charitable hand was found to cover them with the adjacent soil."

**Millardet's Discovery.**—Plant diseases were little known at the time of the Irish famine, and control measures still less known. It will be remembered that bacteria as the cause of human disease were not known until shortly before 1880. In 1883 Millardet, a Frenchman, discovered a chemical mixture composed of copper

sulphate and lime which prevents potato blight. He first used it to control a similar blight of the grape. From 1845 until 1883 the world was almost helpless to combat blights of all kinds. During this time botanists had worked out the life history of several fungus diseases. A knowledge of the life history is usually necessary before control measures can be devised.

**The Life History of Potato Blight.**—The fungus may attack all parts of the potato plant. It winters over in the tubers and is

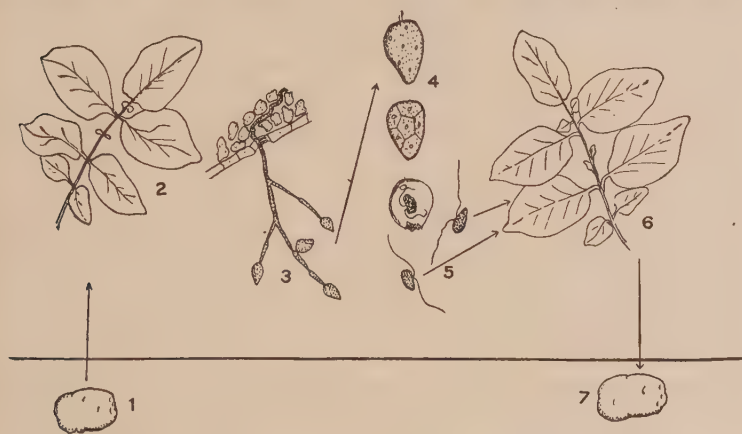


FIG. 213.—Life history of potato blight (*Phytophthora infestans*). 1, a planted tuber which has harbored the disease over winter. 2, a leaf of the plant which grew from the tuber (1) and which is infected. 3, a branch of the fungus growing from a stomate of the leaf and bearing conidia. 4, three stages in the germination of a conidium to form swimming spores (5) which infect a healthy leaf of another plant by swimming through drops of rain or dew to send a growth through the stomates (6). 7, a tuber produced by this plant and a carrier of the disease to the crop of the next year.

planted with them in the spring. It grows as the plant grows until it produces its spores. Hyphæ project through the stomates in the leaves and bear structures called *conidiospores* (Fig. 213) which are capable of floating in air, and may be blown great distances. When a conidiospore falls on the leaf of a potato plant which is wet with dew or rain, it germinates and produces several two-ciliated spores which swim about over the surface of the leaf. They are, therefore, *zoöspores*. If one of these zoöspores succeeds in entering a stomate

of the leaf it will germinate and send forth a hypha which branches and grows through the fibrovascular tissues of the plant to all of its parts. In this manner it stops up the tubes through which sap circulates.

Since the zoöspores are not formed, except in the presence of water on the surface of the leaf, the disease is not spread in rainless and dewless weather; and since the spores are carried by the wind they will not spread far in calm weather; but, suitable weather conditions of wind and moisture are more or less favorable to the spread of the parasite, and these conditions are not under the control of man. If the tubers are diseased, most of them will rot, but some will be sound enough to plant. If diseased potatoes are not planted, the disease will be greatly reduced, but this method of control is not sufficient. Attempts have been made to breed a disease resistant variety, but thus far little progress has been made.

**Bordeaux mixture** is the name of the poison invented by Millardet. It is named after the City of Bordeaux, France. A disease in many ways similar to potato blight was brought over to France along with American grape vines which were resistant to it in America; but the European grape could not withstand it. It was in a successful attempt to control this disease that Bordeaux mixture was invented. This poison in the water on the surface of the leaf kills the zoöspores when they leave their spore cases to enter the stomates. Millardet worked out a solution-mixture which was of such strength that it would do the foliage of the grape no harm but would kill the spores of the grape mildew. This mixture is now used to combat many fungus diseases of plants. The strength differs for different uses, but the following formula is most commonly used:—

|                      |            |
|----------------------|------------|
| Copper sulphate..... | 5 pounds   |
| Stone lime.....      | 5 pounds   |
| Water.....           | 50 gallons |

Mix thoroughly and apply in the form of a fine spray.

Bordeaux mixture is not a *cure* for any disease. It is a *preventive*. After a fungus has once entered a plant it is usually impossible to get rid of it except by pruning the parts which are affected; and, except in the case of trees, this is not advisable.

The conquering of potato blight marks another victory of science over the forces of nature. The potato has been restored to the fields of Ireland, and the people may rest assured that *Phytophthora infestans* will never cause another famine.

**Suggested Project.**—Begin making a collection of various types of fungus diseases. Properly label them and arrange them in a museum case.

**Review Questions.**—Where did potato blight come from? How is it carried over winter? What is its life history? How is it related to wind and moist weather? Why should we always plant healthy potatoes? How is Bordeaux mixture made? How is it used? Is it a cure for potato blight?

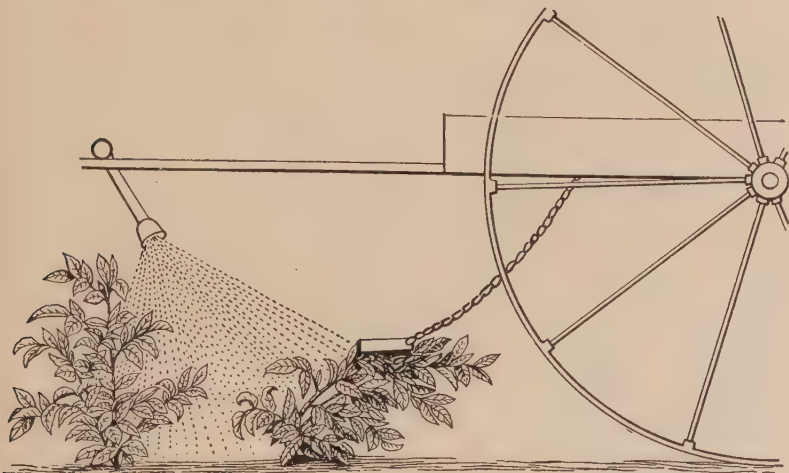


FIG. 214.—A good spraying apparatus for reaching the under surface of the leaves of potato plants. (Courtesy of the Wisconsin Farmer.)

### PROBLEM 3. HOW MAY PLANT DISEASES BE CONTROLLED?

**General Questions.**—Are plant diseases contagious? Are they all alike? Is the treatment for them all the same? What is fire blight. How do we fight it? What are the smuts? How do we fight them? How do we fight the wilts?

We have just studied potato blight and have learned of its life history. By knowing its life history, scientists have discovered



methods of keeping it in check so that potatoes can be raised. If we did not know how to fight plant diseases, a catastrophe as bad as the Irish famine might afflict us at any time, through the destruction of several of our essential food crops.



FIG. 215.—A fire blighted apple twig. The bacteria travel down the twig in the sap ducts and spread rapidly in young tissue. (Vaughn.)

In the cultivation of domestic crops the chances of spreading a plant disease are much greater than in nature. An entire field is planted to one crop. In some sections a grain crop may cover a great area, field adjoining field. If a disease once gets started its spores may be carried by the wind over the entire region, bringing the danger of death to every plant. The agriculturalist must be constantly on the watch for the first signs of danger. Fortunately, most plants possess more or less natural immunity to their diseases; and, consequently, the affliction does not spread as rapidly as it might.

There are several groups of fungi which affect our crops. Some are easily controlled, and some defy our most heroic efforts. Each group must be fought in a special way according to its life history and habit of attack. We will study six representative methods which may be called *pruning*, *spraying*, *seed disinfection*, *crop rotation*, *quarantine*, and *breeding for immunity*.

**1. Pruning.**—*Fire blight* is a disease of the apple, pear, and quince. It manifests its presence by a sudden wilting and blackening of the

blossoms. After a time the twigs also turn black. It may ultimately travel down the twigs and kill the entire tree. It lives over winter in the diseased twigs and may be carried from tree to tree on the feet of birds and insects. It is caused by a bacterium (*Bacillus amylovorus*). If the diseased portions of trees are carefully sought out and pruned away the disease may be checked or cured.

The black rots of plums, cherries, and apples are also controlled by pruning. Wood rot of trees may be carefully removed if not too bad, and the wound thoroughly disinfected, and filled with concrete.

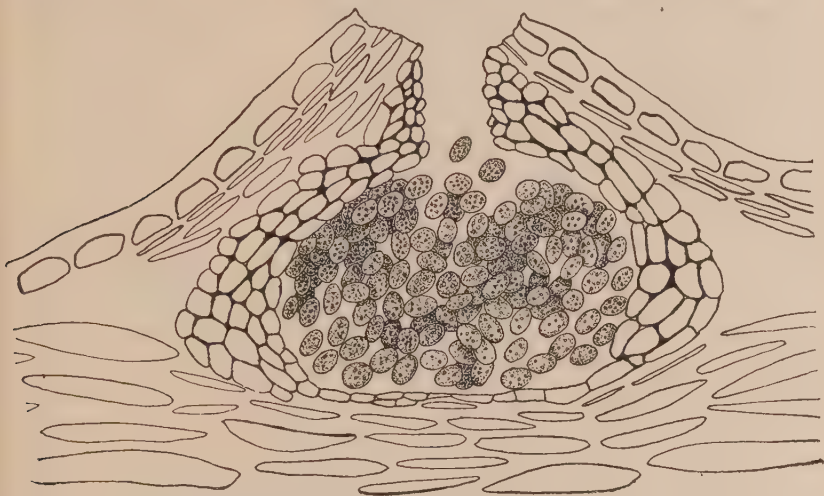


FIG. 216.—A section through a blotch in the skin of a young Ben Davis apple showing the spores ready to be released. (U. S. Dept. of Agriculture.)

However, if the trunk shows shelf or bracket fungi, it is probably too late to save it by surgery; and it should be removed to prevent a further spread of the infection. (See Fig. 215.)

**2. Spraying.**—We have mentioned spraying as a means of preventing grape mildew and potato blight. Other diseases which may be prevented by spraying are the brown rot of peaches, cherries, and plums, early blight of potatoes, scab and bitter rot of apples, and the leaf curl of peaches. The class may study these diseases by means of field trips, preserved specimens in the laboratory, and reports from the latest government bulletins.

**Bordeaux Mixture.**—*Apple blotch* is caused by a fungus. It appears as hard, brown spots on the fruit, cracked areas on the twigs, and brown or yellow spots on the leaves (Fig. 216). It lives throughout the winter on the twigs and produces great numbers of spores in the spring. These spores are carried by the wind and other means to the fruit and leaves. If the trees are properly sprayed with Bordeaux mixture the disease can be controlled. Potato blight is also checked by it as we have seen.

**Lime-sulphur** is another good spray mixture which is extensively used. It is prepared in a strong form for winter use against both scale insects and fungi which winter over on the bark of twigs. Because this strength would kill vegetation, if used in summer, a special mixture containing about 4 lbs. of lime, 4 lbs. of sulphur to 50 gal. of water is used. The lime-sulphur spray mixtures are usually purchased already prepared in a concentrated form and are diluted for different uses according to directions.

**3. Seed Disinfection.**—*Stinking smut of wheat* is caused by a fungus which produces its spores in the kernel. At thrashing time the dead kernels break open releasing the spores. They are distributed over the healthy kernels and germinate with them the next spring. The disease attacks the young plants, usually below ground, and lives in the wheat plant until the kernels are formed, when it again produces a crop of spores which destroy the grain.

If the seed wheat is soaked in formalin (1 lb. of formalin to 45 gal. of water) the spores will be killed and the next crop will be free from the disease.

*Loose smut of wheat* does not destroy the kernel, and its presence can not be detected within. No external application of a poison will kill this parasite, it can be destroyed by soaking the seed wheat in cold water for five hours, and then in hot water at a temperature of 129°F. for ten minutes. If this is accurately done, the seed will not be harmed, and the crop will be free from loose smut.

Soaking in cold water starts the germination of the spores of the smut. The hot water kills them while they are the least able to withstand it. Care must be exercised not to get the water too hot, or the germ of the seed will be killed also.

Each one of the grains is affected by smuts. Some should be made the subjects of special reports and laboratory demonstrations. With the exception of corn smut they can be controlled by one of the methods outlined above. More complete details can be found in the Farmers' Bulletins of the U. S. Department of Agriculture.



FIG. 217.—A smutted panicle of oats and a normal one to show how the grain is destroyed.

**4. Crop Rotation.**—*Cotton wilt* is a disease which attacks the roots of cotton and lives in the soil for many years. No method of eradicating it is known. For this reason, if a soil is affected no cotton must be grown on it for several years. This makes crop rotation necessary. Some fungi which do not live so long may disappear in two or three years. Have reports given on flax wilt, root rot of tobacco,

dry rot of potatoes, and club root of cabbage. See the latest government bulletin on each topic.

5. **Quarantine** is as effective in preventing plant diseases as it is in preventing human diseases. The Irish famine would not have



FIG. 218.—A young cotton plant attacked by cotton wilt. (Orton, *U. S. Dept. of Agriculture.*)

occurred if potato blight had been confined to South America. The Japanese chestnut is fairly resistant to the chestnut bark disease. This disease has recently attacked the chestnut trees in America, and will probably kill all of our trees throughout the country, for no means of combatting it is known. It is of the utmost importance



that we keep out diseases which are known in foreign countries, and a quarantine is now rigidly enforced against several by the U. S. Department of Agriculture. (See Fig. 315.)

**6. Breeding for Immunity.**—*Cotton wilt* and *watermelon wilt* have been controlled by breeding. The first by selection and the second by hybridization.

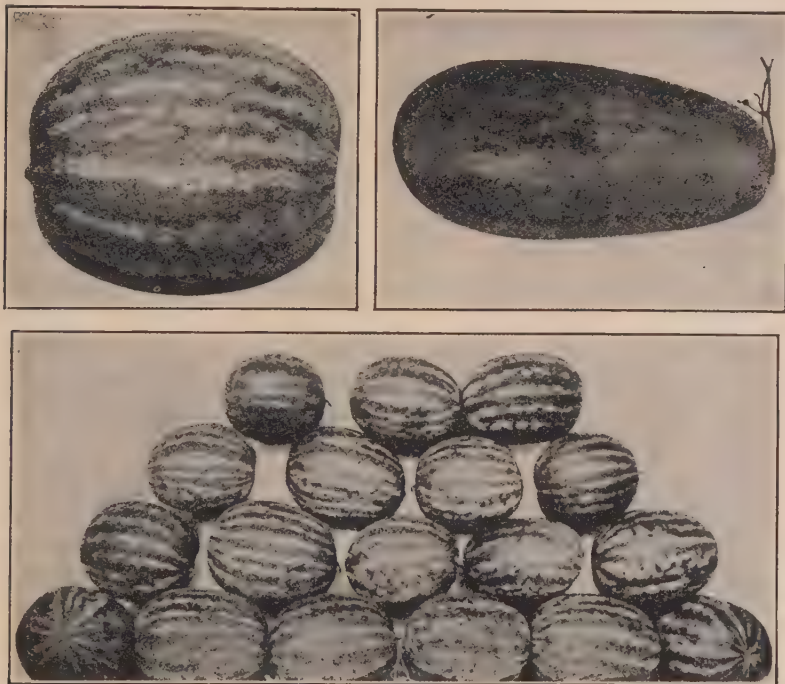


FIG. 219.—An example of plant breeding for disease resistance. The parents are the citron and the watermelon shown above, and the watermelon-citron hybrids of the third generation are shown below. (Orton, U. S. Dept. of Agriculture.)

Breeding for disease resistance by *selection* may be illustrated by what has been done by U. S. Department of Agriculture and independent planters in developing strains of Sea Island Cotton which are resistant to cotton wilt, a fungus disease which we mentioned in considering control by crop rotation. The soil of certain

cotton lands became so infested with the fungus that it was impossible to continue raising the crop, but in fields which were affected certain individual plants were found which withstood the disease. Seed from these was saved and planted. By continuing this process of selection several strains have been produced which will grow satisfactorily on soil which harbors the fungus. Strains of cabbage which resist disease have been selected in a similar manner.

Breeding for disease resistance by *hybridization* may be illustrated by what has been done to develop a watermelon which will resist wilt, another fungus disease which is similar to cotton wilt.

About 120 different varieties of watermelons were tested, but no individuals were found which showed a sufficient degree of resistance to be used as a basis for selection. However the citron is resistant to the disease, and by crossing a variety of watermelon called the Eden and a citron, hybrids of "wonderful vigor and productiveness" were produced in the second generation. None of these, however, were edible. In the third generation 3,000 or 4,000 plants were raised, and the best ten chosen from which to raise the fourth generation. By further hybridization with the Eden parent, and after several years of selection, a good melon which is disease resistant was obtained.

Breeding plants and animals for improved resistance to disease is a new field of biological research from which we may expect valuable results. It is especially important, because when a plant is resistant to disease, it is no longer necessary to spend time and money fighting its ravages with sprays and other expensive preventives.

**Review Questions.**—Why are diseases of domestic plants more contagious than diseases of wild plants? How does fire blight affect a plant? On what plants does it live? How may it be controlled? What two materials are used as sprays? For what diseases are they used? How does stinking smut differ from loose smut? How do we treat seed wheat which has stinking smut? How do we treat seed wheat which has loose smut? How does crop rotation help in the fight against cotton wilt? How does quarantine help in the fight against plant diseases? How was cotton selected to prevent disease? How were watermelons bred to prevent disease?

## References on Plant Diseases

## Elementary

- Bergen and Caldwell, *Practical Botany*, Ginn & Co.  
Moore and Halligan, *Plant Production*, American Book Co.  
Waters, *Essentials of New Agriculture*, Ginn & Co.

## Advanced

- Harshberger, *Plant Pathology*, P. Blakiston's Son & Co.  
Duggar, *Fungus Diseases of Plants*, Ginn & Co.  
Stevens, *Fungi which Cause Plant Disease*, Macmillan Co.  
Stevens and Hall, *Diseases of Economic Plants*, Macmillan Co.

## PROBLEM 4. WHAT IS THE CAUSE OF HUMAN DISEASES?

**General Questions.**—How do we know that bacteria cause disease? Are all diseases caused by bacteria? What worms may cause disease? What diseases are caused by protozoans? How do we get malaria? What is the life cycle of the disease? How may it be cured? How was it proven that tuberculosis is caused by a bacterium? Is it inherited? Can it be cured? What is the nature of cancer?

Can we prove to ourselves that bacteria do cause disease? We may try an interesting experiment which is shown in the illustration. If we inoculate a healthy fruit with bacteria from a diseased spot on another fruit, and wait a few days, we may get the results which are shown in Fig. 220. If we do, are we not forced to conclude that it was bacteria which caused the healthy fruit to decay?

**What is the relation of bacteria to disease?**

**Disease** is a condition of the body in which it is prevented from functioning normally. Disease may be due to a variety of causes. We will study the tapeworm, the hookworm, and trichina as worms which cause disease in man. Malaria, yellow fever, sleeping sickness, and possibly smallpox are due to protozoans. Tuberculosis, influenza, pneumonia, diphtheria, typhoid fever, whooping cough, bubonic plague, and hydrophobia are caused by bacteria. Asiatic cholera, relapsing fever, and syphilis are caused by spiral bacteria. Rheumatism, cancer, apoplexy, and goiter are not believed to be caused by microbes. Feeble-mindedness, epilepsy, paralysis, and



FIG. 220.—A scientific experiment to test the cause of disease. The tomato on the left was inoculated with bacteria (*Bacillus corotovorius*) from a decayed spot on a diseased tomato. The one on the right was not inoculated. Within four days the upper part of the inoculated fruit was destroyed. Repeat this experiment with other fruits. Are the conclusions that bacteria cause disease well founded? In these days of "faith cures" such experiments can not be too strongly stressed in schools.



FIG. 221.—Male and female mosquitoes which cause malaria (*Anopheles quadrimaculatus*). Note the beautiful antennæ on the male. (U. S. Dept. of Agriculture.)

some forms of insanity are nervous diseases which are due to an inherited defective nervous system. Thus we see that the question of the cause of disease is a large one.

**Malaria.**—Protozoans of the genus *Plasmodium* are the cause of malaria. There are at least three species causing three kinds of malaria in man. Other forms are parasites in other animals, especially birds.

We shall attempt only a brief outline of the life history of *Plasmodium*. If a mosquito which carries malaria bites a person, worm-like

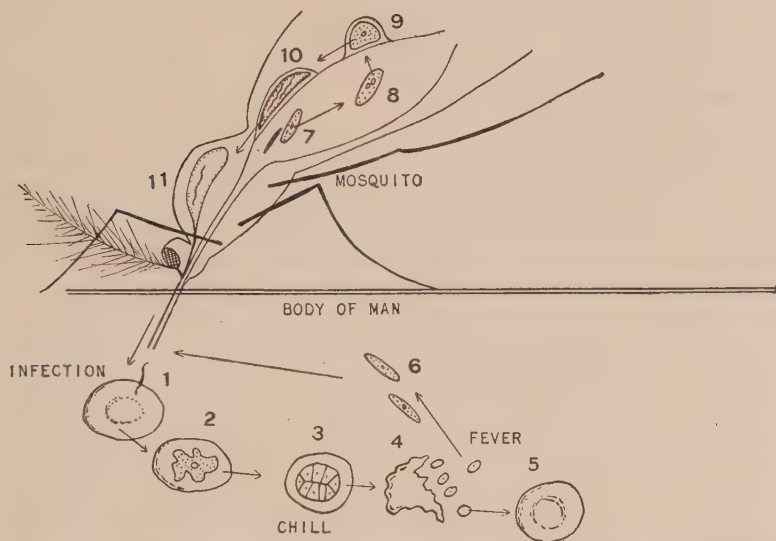


FIG. 222.—Diagram of the life history of the malarial parasite to show its relation to man and the mosquito, and how it causes a chill and fever.

cells, called *blasts* (Fig. 222, 1), enter the blood with the saliva which is injected by the mosquito to prevent the blood from coagulating. These blasts bore into a red corpuscle and take on an amoeboid form (2). This amoeboid cell forms many spore cells which nearly fill the corpuscle and cause it to cease functioning (3). This causes the chill. The corpuscle breaks, and the spores escape together with the poisonous waste products of their metabolism (4). This poison



causes the fever. These spores may enter other red corpuscles to repeat the process and cause another chill in forty-eight or seventy-two hours (5); or some of them may be sexual cells which will conjugate if they are taken up in a red corpuscle by a mosquito (6). The female cell becomes rounded, and the male cell assumes a spindle shape. Conjugation between these cells takes place in the stomach of the mosquito (7). An elongated cell results (8). It bores into the stomach wall and forms a cyst (9). In about two weeks the cyst is greatly enlarged and filled with a great number of long, slender, but very minute blasts (10). They emerge into the body cavity and make their way to the salivary glands (11), and thus enter the blood of the next person attacked by the mosquito.

Malaria was formerly thought to be due to vapors which arise from the surface of swamp water, because the disease occurred more abundantly near such places. Malaria is known to have affected man since the earliest times; but not until 1880 was its cause known when Laveran, a French scientist living in Algiers, found the protozoön which causes it in the blood of malaria patients.

The great biological discovery which marked the close of the nineteenth century was that malaria is carried by the female mosquito of certain genera and species of ANOPHELINÆ. Since the disease is carried only by this genus of mosquito, if we can prevent it from breeding there will be no malaria. This seems a simple matter, but the mosquito may breed anywhere that water stands for some time. Its young have been found in eaves gutters, tin cans, hollow trees, watering troughs, park fountains, rain barrels, and countless other places where water stands.

Another way to prevent the disease is to isolate all people who have it, and, thus, prevent the mosquitoes from becoming infested. This is also very difficult for many people have it in a mild form and do not consult a physician. Still another way to prevent the disease is to avoid being bitten by mosquitoes, but this is also difficult to accomplish in practice.

Malaria can be cured by taking quinine at such a time that it will be present in the blood when the microbes are released from the red blood corpuscles at the time when the fever occurs (Fig. 222-4).

All cases of malaria should be promptly treated and cured. The disease greatly weakens the system and lowers its resistance to other diseases. It very seldom happens that people die of malaria, but the losses in interruption in employment and reduced efficiency amount to millions of dollars in the United States annually, not to mention the physical suffering which it causes. Malaria can be prevented entirely only by education and coöperation. Will you do your part?

**Tuberculosis** may serve as an example of a disease which is caused by a bacterium. In former years it was the worst scourge of the human race, but now in Wisconsin and several other states it ranks about fifth in the deaths which it causes. This is a fine compliment to the success and energy of scientists who have given their time and energy to the fight against it. Until the discovery of bacteria as the cause of disease it was thought to be a constitutional disease and to be inherited because it "ran in families." In 1882 Koch, a German bacteriologist, discovered the bacterium which causes it. He grew the microbes in a pure culture and inoculated guinea pigs with them, and produced the disease in the guinea pigs.

This is the test which must be applied when a new disease producing bacterium is found. It must be present in the patient suffering from the disease, it must be raised in pure culture, and the disease must be produced by the bacteria when an animal or man is inoculated with them.

Tuberculosis has a tendency to run in certain families for at least two reasons—(1) If one member of the family has the disease other members are exposed to it and may take it. (2) Some families are by inheritance less able to resist certain diseases than other families are. This point will be discussed under the heading "Immunity" in the next study.

No medicine is known which will cure tuberculosis because no germicide (germ poison) has been found which can be put into the lungs to destroy the bacteria, and which will not have a bad effect on the patient. However, if the presence of the disease is known at an early stage it need not prove fatal.

**Tuberculosis can be cured** by observing perfect rules of health. Fresh air, rest, and special food are the conditions upon which the

cure chiefly depends. It is of the greatest importance that the presence of the disease be known before it has made much progress for after the body has become too much weakened it is usually too late to effect a cure.

**SUNLIGHT.****OUT-DOOR AIR.****GOOD FOOD.****REST.**

FIG. 223.—Four items in the formula for the cure of tuberculosis. (*New York State Department of Health.*)

**Prevention of Tuberculosis.**—The sputum from persons who have tuberculosis contains tuberculosis bacteria. It should be collected in cups and burned. No one, not even well persons, should be allowed to spit in public places. The germs may also be scattered

by coughing and sneezing. There is some possibility that cattle tuberculosis is caused by the same bacterium which infests man. Until we are certain that man can not contract tuberculosis from

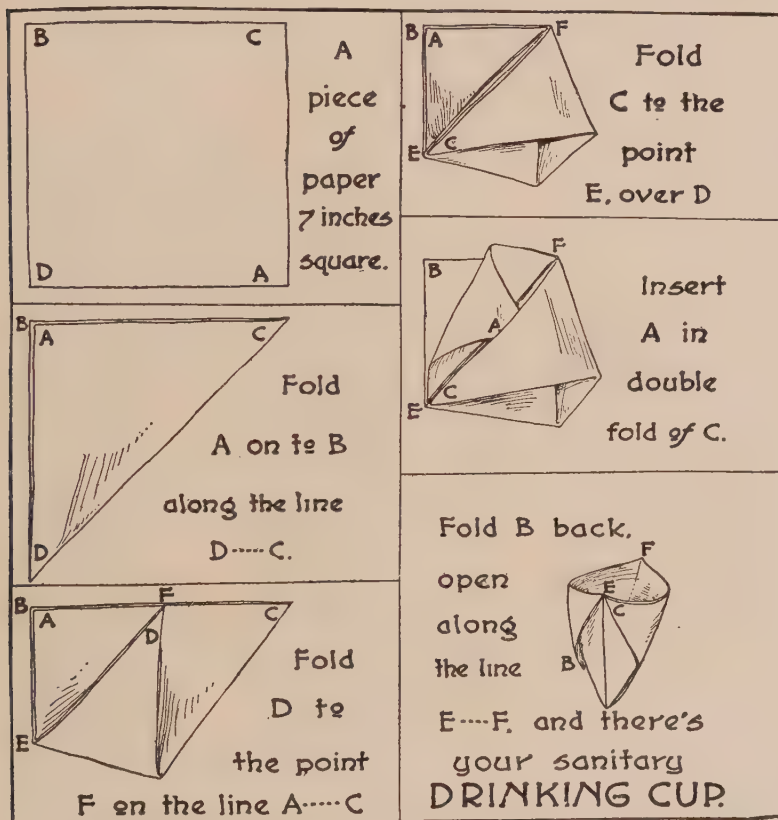


FIG. 224.—How to make a sanitary drinking cup. (Michigan State Department of Health.)

cattle we should exercise the greatest care in providing a milk supply from inspected, healthy cattle.

*We should look upon any one who spreads tuberculosis as being guilty of murder. It is just as wicked to give your neighbor disease as it is to give him poison.*

**Cancer** is a very common and highly fatal disease. It will serve as an example of a disease which probably is not caused by microbes. It is most apt to occur between the ages of forty-five and sixty-five, and may affect most any part of the body. It is an enlarged growth of the cells of the organ which is affected. These cells become enlarged and continue to grow unchecked until they become inflamed,

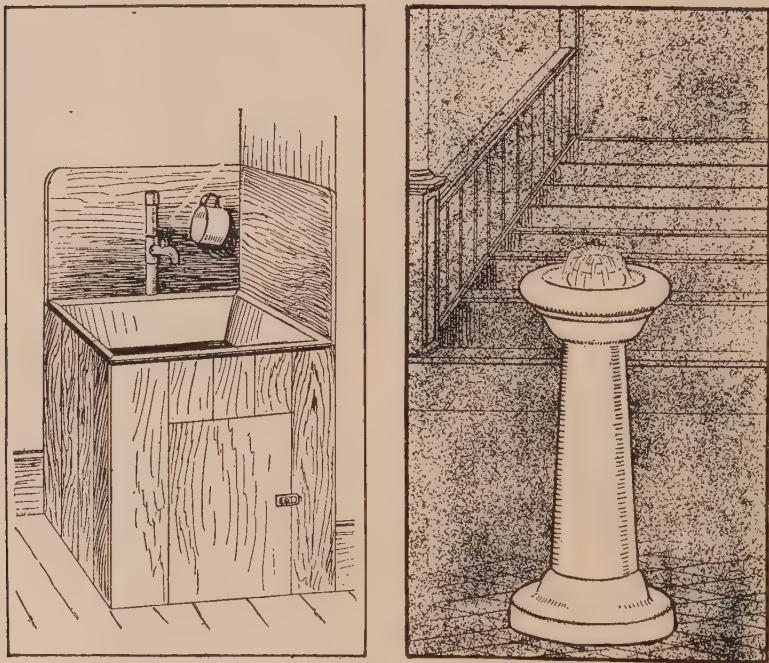


FIG. 225.—The old way and the new way, representing the progress made in one generation in the sanitation of supplying school children with water. (*Michigan State Department of Health.*)

and finally the growth may spread to neighboring tissues and in the end cause death.

Recent researches seem to show that cancer is not due to a microbe, is not contagious, and is not inherited. While all authorities seem to agree that it is not due to a microbe at its beginning, it is known to give forth much pus, containing bacteria, when it is well advanced.



It is also generally agreed that cancer is not contagious in the ordinary sense of the idea of contagion, but it may be transferred to another by grafting or inoculation. As to its running in families, there is dispute. Some researches seem to show evidence which indicates that it runs in families because of an inherited tendency to develop it. Of course the disease itself can not be inherited.

*Cancer is believed to be caused by irritation which is prolonged.* Neglected sores and ulcers, constant rubbing of the skin, continuous pressure, and unchecked inflammation are believed to be the chief causes of cancer. Any lump or persistent sore should be reported to a specialist at once, for if it is a cancer it can be removed if operated on while it is small. After it is easily recognizable as a cancer its removal may be impossible. *Cancer can be cured in but one way, and that is to cut it out.* Electrical, violet ray, and radium treatments are usually of but little value and should not be resorted to except in cases where an operation is impossible or inadvisable. No reliance whatever should be placed in any drug or poultice.

**Review Questions.**—Describe the experiment to prove that bacteria cause fruit to rot. Describe the cycle of the life of the malarial parasite in the body of man. What causes the chill? What causes the fever? Why is it difficult to prevent mosquitoes from breeding? Why is it difficult to isolate malarial patients? How may malaria be cured? What sign of progress in fighting tuberculosis may be noted? How did Koch prove that it is caused by a bacterium? What is the prescribed method of curing tuberculosis? What are some of the precautions which we should observe against its spread? Why is the public drinking cup dangerous? What is the nature of cancer? Is it contagious? How is it believed to be caused? What is the method of getting rid of a cancer?

#### PROBLEM 5. HOW MAY CONTAGIOUS DISEASES BE CONTROLLED?

**General Questions.**—What is meant by immunity? Are all races equally immune to disease? Is immunity inherited? May immunity be acquired? Which bacterial diseases may we have the second time? Which diseases leave us immune to them? How does vaccination produce immunity? What other

**methods are there of acquiring immunity? How do we prevent diphtheria and typhoid fever? What is the value of quarantine?**

Before the practice of vaccination as a means of preventing small-pox became common, nearly every one had the disease. It is said that not one in ten escaped. Thousands died, and those who lived frequently carried the scars of it on their faces for life. There were, indeed, few beautiful women with unscarred faces in those days.

To-day, there are 200 cases per 100,000 in Kansas where no compulsory vaccination law is in force and 2.6 cases in New York where a compulsory vaccination law is enforced. Surely, this is an important matter about which we should all be much more concerned than we are. Can other states do what New York has done? In this study we shall consider some of the successful methods of fighting contagious diseases.

**Immunity.**—In the previous study we mentioned the fact that some families are more likely to have tuberculosis than others. When an individual is able to perfectly resist the attack of disease-producing bacteria, he is said to be *immune*. Immunity may be of two kinds,—*natural* and *acquired*.

**Natural immunity** occurs when an individual possesses an immunity which he has inherited. The white man is fairly resistant to influenza and tuberculosis because his ancestors have had these diseases for countless generations. The families which have been resistant have survived and left offspring who were also resistant like themselves; and those who were not resistant have died of the disease whenever they have had it. In the winter of 1918-19 when the epidemic of influenza swept around the world, the population on some of the islands of the Pacific Ocean was almost completely wiped out. The American Indian and the Eskimo have a very low resistance to tuberculosis because the disease did not affect them until they came into contact with the white race.

In general a bacterial disease is confined to one species of plant or animal, and other species are said to be immune to it; but some diseases—such as hydrophobia, tuberculosis, anthrax, and hoof and mouth disease—may affect several species.

**Toxins.**—The theoretical explanation of immunity is very simple. When disease producing bacteria live in the body they give off

waste products which are poisonous, much the same as yeast produces alcohol. These poisons are called *toxins*. If they are produced in great quantity, and are not thrown off or neutralized in the body, death will result.

**Antitoxins** are fluids which the body produces to counteract the toxins produced by the bacteria. If antitoxins are present in the blood in sufficient quantity, the individual will not have the disease at all. He is *immune*. If he is able to produce antitoxin faster than the bacteria produce toxin, he will recover. If not enough antitoxin is produced, the bacteria will multiply and the case will result fatally.

**Acquired immunity**, then, is due to the fact that a sufficient amount of antitoxin is constantly maintained in the blood to prevent a recurrence of the disease. It may be acquired by an individual in four different ways—(1) by having the disease and recovering from it, (2) by vaccination, (3) by being injected with an antitoxic serum, and (4) by being injected with a toxin.

1. It is well known that people who have had measles, smallpox, whooping cough, diphtheria, mumps, and scarlet fever do not usually have the disease the second time. This ability to resist a second attack is an *acquired immunity*. However, all diseases do not produce an immunity in those who recover from them. Pneumonia, influenza, and boils may be had an indefinite number of times. In these cases the immunity which is developed during the course of the disease, and which enables the patient to throw it off and get well, is not permanent. It is said to be *passive*. In some cases of passive immunity, such as influenza and pneumonia, the antitoxin supply is not maintained in the blood for very long, and when it is gone the person may have the disease again.

2. **Vaccination** prevents smallpox. The word comes from the Latin *vacca*, a cow. People sometimes caught cowpox from cattle. These people were immune to smallpox. This knowledge led to the practice of vaccination. Edward Jenner (1749-1823) proved, by a series of brilliant experiments, that cowpox is a form of smallpox, and that having had it makes one immune to smallpox. The immunity lasts for several years, due to the fact that antitoxin con-

tinues to be produced by the body long after the disease has been thrown off.

Vaccination, then, is a means of causing the body to produce antitoxin. It is done by inoculating, or injecting, either living germs, or dead germs, into the body. The toxin which they produce, or which is injected with them, causes the body to produce antitoxin. Vaccination is also used against typhoid fever, hydrophobia, and hog cholera.

**3. Antidiphtheric serum** is an antitoxin which has been elaborated in the blood of the horse. Parke, Davis and Co. describe its production as follows:

"Diphtheria bacilli are planted in beef bullion, where they multiply rapidly. Then they are killed by the application of a powerful germicide, and removed by filtration. The clear filtrate contains the toxin, which is injected into the horse in small but gradually increasing doses. In time the animal acquires a tolerance or immunity to the toxin, antitoxin being developed in his blood. Then he is bled; and the blood-serum, separated and purified, constitutes *antidiphtheric serum*."

It seems that the antitoxin which is produced in the horse is the same as that which is produced in the human body. Experience shows that after the serum is injected the progress of the disease stops. If it has not already done enough damage to cause death, the patient will recover. Hundreds of lives have been saved by its use, and diphtheria is no longer the dreaded disease which it once was. No child need ever die of diphtheria. If the diagnosis is properly made, and in time, recovery will follow the use of the antitoxin. All cases of sore throat which are accompanied by a fever should be reported to a specialist at once.

If the antitoxin is used and no case of diphtheria is present, the immunity due to the antitoxin will last only until the system gets rid of the serum; and the cells of the body will not replace it after it is gone. The presence of toxin in the body causes the cells of the body to produce antitoxin, but the presence of antitoxin does not cause its own production. Hence, immunity gained by an injection of antitoxin is passive, whereas immunity resulting from vaccination is permanent, at least for a long time.

**4. Toxin Injection.**—We have mentioned the fact that when the horse is injected with the toxin of diphtheria an antitoxin is produced in its blood which counteracts the toxin, and that a superfluous quantity of the antitoxin remains in the blood. This renders the horse immune. It is an example of the fourth method of acquiring immunity.

This method of producing immunity is coming into greater use yearly. A very efficient combination of both toxin and antitoxin is now injected into children to render them immune to diphtheria. The antitoxin is an immediate producer of immunity, and the toxin stimulates the body to acquire its own permanent immunity. It is usually given in three injections. The second is more powerful than the first, and the third is still stronger,

Dr. Bela Schick has developed a test to determine the degree of immunity possessed by children to diphtheria. If the child is not sufficiently immune, the toxin-antitoxin injection is given. Several tests have been developed to determine whether or not a suspect has a contagious disease. They are of great value to the physician, because they make it possible for him to detect the presence of the disease before the more evident symptoms set in.

**Quarantine.**—Every person who has a contagious disease got it from some one else who had it or from some animal which was affected. If people who have contagious diseases would be careful not to spread them, such diseases would disappear entirely. Biologically speaking, any one who gives a disease to another by breaking quarantine, spitting in public places, or by general carelessness may be as guilty of murder as if he had killed his victim with a shotgun. How long will it be before we are well enough educated as a people to rid ourselves of contagious diseases!

**Review Questions.**—What progress has been made against the ravages of smallpox? Why are our diseases very dangerous to Eskimos, and natives of the islands of the Pacific Ocean? Where do toxins come from? Where do antitoxins come from? What is passive immunity? How was vaccination discovered? How is antidiphtheric serum produced? Does it produce permanent immunity? For what is the Schick test given? If the child is not immune, what is done? Why do we quarantine?



| Diseases                             | Periods of incubation by days |       | Periods of communicability                                                                                      |
|--------------------------------------|-------------------------------|-------|-----------------------------------------------------------------------------------------------------------------|
|                                      | Limits                        | Usual |                                                                                                                 |
| Cerebrospinal meningitis (epidemic). | 2-10                          | 7     | During course of disease and while the disease bacteria are present in nose and throat.                         |
| Chicken pox.....                     | 14-21                         | ..... | While scabs are present on mucous membranes and skin.                                                           |
| Diphtheria.....                      | 2-5                           | ..... | While the disease bacteria are present in secretions and lesions.                                               |
| German measles.....                  | 10-21                         | ..... | Eight days from onset.                                                                                          |
| Infantile paralysis.....             | 3-10                          | 6     | Unknown. Apparently not more than 21 days from onset.                                                           |
| Influenza.....                       | 2-5                           | ..... | Unknown. Probably until four days after temperature is normal.                                                  |
| Measles.....                         | 7-18                          | 14    | During period of catarrhal symptoms and while there are abnormal mucous membrane secretions.                    |
| Mumps.....                           | 4-25                          | 18    | Two weeks after onset and one week after disappearance of swelling.                                             |
| Scarlet fever.....                   | 2-7                           | 3-4   | Four weeks from onset and while there are abnormal discharges or open sores.                                    |
| Smallpox.....                        | 12-21                         | 14    | From first symptoms to disappearance of all scabs and crusts.                                                   |
| Typhoid fever.....                   | 7-23                          | 10-14 | From onset of symptoms until the disease bacteria are absent as shown by repeated bacteriological examinations. |
| Whooping cough.....                  | 1                             | ..... | During catarrhal stages and while characteristic whoop is present.                                              |

FIG. 226.—Table of information about communicable diseases.

## References on Contagious Diseases

Bulletins of the U. S. Public Health Service, Washington, D. C.

Bulletins of the Public Health Departments of our large cities.

Bulletins of the several state's boards of health. Write to the State Board of Health, State Capitol. All of these bulletins are free.

## PROBLEM 6. HOW DO PARASITIC WORMS GET INTO THE BODY OF MAN?

**General Questions.**—What damage do parasitic worms do? How do we get tapeworms? How does a tapeworm grow? How does the hog get the larva of the tapeworm? How do round worms get into our intestines? What is the life history of trichina? How do we get hookworms? How may we be free from worm infestations?

Worms are not so common as parasites of mankind as they formerly were. All of our sanitary precautions against bacterial diseases help to reduce the number of infestations from worms. The number of kinds of worms which frequently, or occasionally, attack man is greater than is generally known. Braun in *The Animal Parasites of Man* lists 40 tapeworms and their relatives, and 43 round worms which may infest man. Fortunately there are only a few which are common and which cause much trouble.

People very seldom die of worm diseases. The danger of worms is in the weakness of the general condition of the body which they cause. While suffering from worms, the system may be invaded by bacteria which may do great damage, or even cause death. The presence of worms in our system reduces our capacity for work, and by this means our economic worth is reduced.

Knowledge is power. If we know the life history of a worm parasite, we are prepared to fight off its attacks, because we know how to avoid it and also how to get rid of it. This problem will be concerned with the life histories of some of our worst worm enemies.

**Tapeworms** are found as adults in the intestines of many of the vertebrate animals. They require two hosts to complete their life history, and alternate with some animal that is eaten by the vertebrate host. *Tænia solium* is parasitic in the alimentary canal of man, and passes its larval stages in the pig. As shown in the illustration,



When the proglottids become mature they pass out of the body of man, and may be taken into the body of a pig; or a single egg may become separated from the proglottid and enter the mouth of a pig with the water or food. If this happens the egg develops into a microscopic worm which bores its way through the alimentary canal of the pig and comes to rest in a muscle. If the meat of the pig is eaten by man without being cooked the larva emerges from its cyst in the muscle tissue and develops into an adult in the alimentary canal of man.

There has been some dispute among zoölogists as to whether a tapeworm is one, or many worms attached together. The scolex may be looked upon as an asexual generation which buds off proglottids which are sexual. Thus there is an alternation of generations.

**Ascaris** (Fig. 228) is a genus of roundworms which is widely distributed in nature. They inhabit the intestines of many vertebrate animals, and usually do not require any other host to complete their life history. They lay large quantities of eggs which pass out from the body of the host with the excreta. If these eggs enter the mouth of another person and are swallowed, they hatch, and become parasites in the intestine. The sexes are separate.



FIG. 228.—Male and female *Ascaris lumbricoides*, the round worm which lives in the intestine of man. The small one with the hooked tail is the male. The adults attain a length of from six to ten inches.

Aside from the fact that the female *Ascaris* lays large numbers of eggs it has few of the characteristics of parasites, and lives an active life in the intestine of its host. They are often a source of great annoyance to children, but can be easily killed and expelled by giving *santonin* followed by a physic.

**Trichina** (Fig. 229) (*Trichinella spiralis*) is another roundworm of small size which may be a parasite in man. It is gotten by eating

uncooked pork in which the larvæ are encysted. When the pork arrives in the stomach, the cyst is dissolved by the digestive juices, and the worm is released. They are male and female, and after mating the female produces many young which hatch from the egg before it is laid. The young bore through the intestinal wall and come to rest in a muscle. This same process is gone through in each host which the trichina enters. Many young trichina boring in the muscles set up a fever which often proves fatal to man. Compare the life history of trichina with that of the tapeworm.

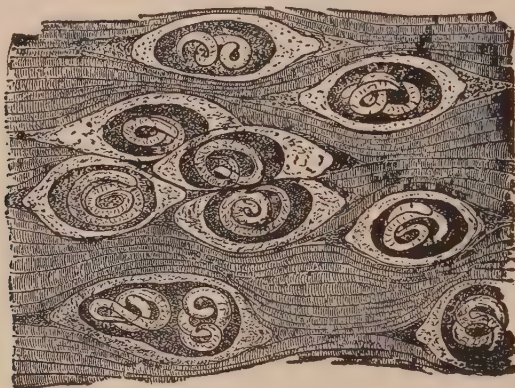


FIG. 229.—Larva of trichina encysted in the muscle of pork. (Ziegler.)

**The hookworm** (*Necator americanus*) is a parasite of the intestines of man in the southern states. It bores into the wall of the intestine and feeds on the blood of its victim. It also injects a fluid into the wound to prevent coagulation of the blood so it can feed freely. This causes a considerable loss of blood, and exposes the intestines to infection by bacteria. People who are badly infested with hookworm are pale, stunted, have swollen abdomens, and a lazy disposition. It is estimated that two million people in the United States are infested with this parasite. It can be expelled by giving thymol followed by Epsom salts.

The hookworm's eggs pass out of the intestine with the excreta. They hatch, and the larvæ live in the soil for some time. If they come into contact with a person's foot, they bore through the skin,



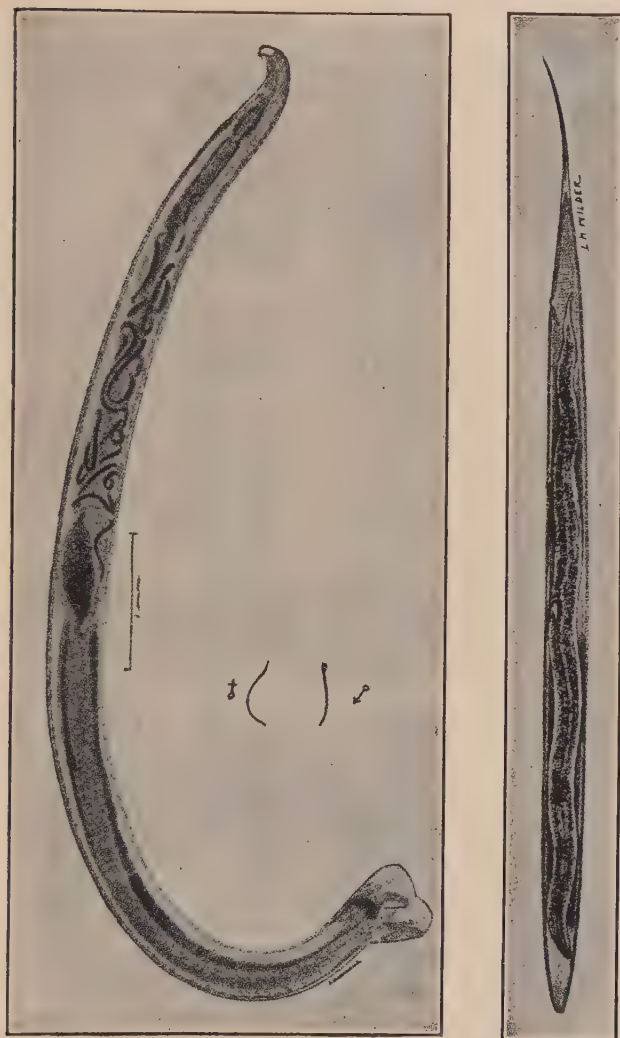


FIG. 230.—The hookworm, adult above, and larva below. The small figures indicate the actual size of the worms. (*U. S. Public Health Service.*)

enter the blood vessels, and are carried to the lungs where they bore through the tissue to the interior of these organs, and make their way to the stomach through the trachea and esophagus. The damage done by hookworms can be checked by a proper disposal of sewage, and a decrease in the practice of going barefooted which is so common among the people of the southern part of the United States.

**Laboratory Suggestions.**—Let the students work out diagrams of the life histories of the tapeworm, trichina, and the hookworm. Put some of them on the board and discuss them in class.



FIG. 231.—Three victims of the hookworm. Note the puffiness about the eyes and the lazy appearance of their poise and dress. (*U. S. Public Health Service.*)

**Review Questions.**—Are there many worms which infest mankind? Where do adult tapeworms live? How does the tapeworm get its food? Outline the life history of the tapeworm. How do ascaris worms complete their life cycle from egg to worm? Give the life history of trichina. How may we avoid getting trichina? In what way does the hookworm affect man? How do they get from one person to another in completing their life history? What should be done to avoid hookworm by people who live where it is common?

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**PROBLEM 7. HOW ARE FLIES RELATED TO HUMAN DISEASES?**

**General Questions.**—In what parts of the world are house-flies found? What is the life history of the fly? How do flies carry diseases? What diseases are carried by flies? How may flies be controlled?

The house-fly is found on all continents and goes wherever man does. It is a pest which man will always have to contend with and *is the greatest living enemy of mankind*. Fifty years ago the fly was thought to be harmless. Some naturalists, thinking all life must be of some value to man, even wrote about the usefulness of the gentle creatures! The author remembers being taught when he was a boy to rescue them from drowning in milk pans. All this has changed with an increase in biological knowledge. The biological facts which are known about the fly alone are worth more to the world than the cost of all of its schools and universities combined. But let us examine the life history of the fly, and then make out our indictment.

**Life History.**—The female fly lays about 120 eggs at a time and usually lays four times. How many eggs all together? It is estimated that about 95% of the eggs are laid in horse manure. One pound of this material may support 1,200 fly larvæ. If your city still has manure piles estimate the weight of the nearest one, and calculate the number of flies which it may produce. Estimating 8,000 flies to the quart, how many quarts would this be?

The time of development of the fly from the egg to the adult varies considerably with the abundance of food, but under favorable conditions a fly may become adult in ten days. At this rate there may be ten to thirteen generations in a summer. Each fly passes through four stages in its growth. They are approximately: egg,  $\frac{1}{3}$  day;

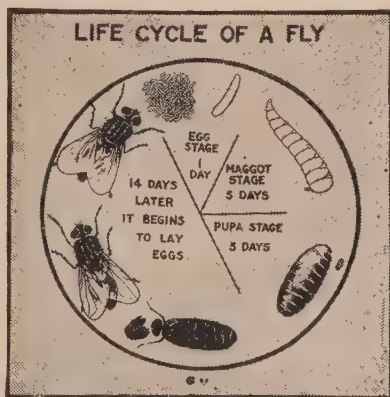


FIG. 232.—The life cycle of the fly.  
(International Harvester Co.)

larva, 5 days; pupa, 5 days; adult, length of life varies from a few days to all winter. A few flies winter over in the form of the adult, but most of them winter over in manure piles in the form of pupæ.



FIG. 233.—The foot of the house-fly. (From "*American Insects*," by Kellogg; Henry Holt and Company, Publishers.)

### House-flies carry disease germs.

This is the complete indictment in one sentence. So far as is known they do no other harm to man. Their presence would be annoying only. It is not known that such specialized diseases as malaria, yellow fever, Texas fever, and cancer can be carried by flies, but many contagious diseases may be carried by them.

The fly is known to carry disease germs in three different ways: by carrying them on its body and legs, by regurgitating them, and by



FIG. 234.—A fly regurgitating food and bacteria. (U. S. Public Health Service.)

leaving them in its fly-specks. Each of these methods requires some special discussion.

1. **The fly's foot** is very well adapted for carrying bacteria. It consists of two sticky pads, two claws, and many hairs which take up bacteria as a brush does paint. Wherever the fly goes the bacteria are left in its foot tracks. The Connecticut Experiment Station found 6,600,000 bacteria on a fly from a swill barrel.

2. **Regurgitation of food** occurs when the fly has had a hearty meal and over eaten. After the fly has fed at the swill barrel, garbage can, privy, or on sputum from a tuberculosis patient it may enter the house and regurgitate (spit up) some of its stomach contents on food which is to be eaten. Although the thoughts of this are unpleasant, it would do no harm if there were no disease producing

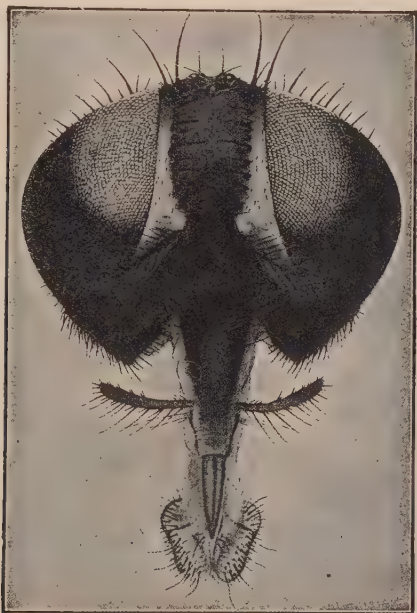


FIG. 235.—The head of the house-fly. Note the mouth which is fitted for lapping food. The compound eyes are very large. Find the three simple eyes at the top of the head. (From *Herms, Medical and Veterinary Entomology*, by Permission of the Macmillan Company, Publishers.)

bacteria present, as is usually the case; but sometimes harmful bacteria are present. These bacteria may enter the alimentary tract of man or domestic animals and produce disease. (See Fig. 234.)

Unlike many other flies the house-fly is unable to bite. The stable-fly often bites in rainy weather and by many is mistaken for the house-fly. The mouth parts of the house-fly are unsuited for taking up solid food or for puncturing the skin of a plant or animal.



When a fly eats sugar it regurgitates some fluid from its stomach which dissolves some of the sugar crystal. Then it draws the dissolved sugar into its stomach.

3. **Fly-specks** are the excreta deposited by the fly. When a fly is well fed it may deposit 100 specks in a day. The digestive juices of the fly are very simple. It has been shown by experiment that many bacteria, including some of those which cause diseases in man, may pass through the alimentary canal of the fly and remain alive and capable of producing disease. The fly's digestive juices are, evidently, not very powerful.

**Fly diseases** are those which are carried by flies. Of these typhoid fever leads the list. It may be prevented wholly, and it is a disgrace

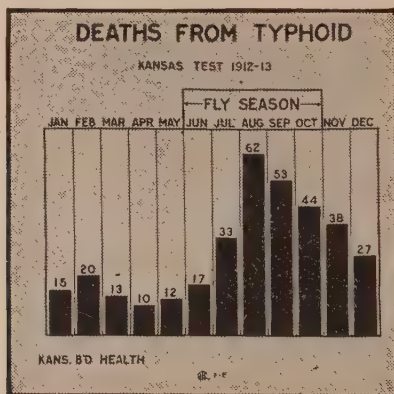


FIG. 236.—A chart showing how the deaths from typhoid fever reach their maximum at the time when flies are most abundant. This is not merely a coincidence; it is a matter of cause and effect. (*International Harvester Co.*)

to any community to have an outbreak (Fig. 236). The germs which cause most all intestinal diseases may be carried by the fly, particularly summer complaint and cholera. In 1914, 140,000 persons suffered from typhoid fever in the United States and 14,000 died of it. Annually 70,000 infants die in the United States of contagious intestinal diseases. Other diseases which are known to be carried by flies are sore eyes, sores, anthrax, spinal meningitis, leprosy, syphilis, gonorrhea, and yaws. Besides these there is good

reason to believe that the fly is to some extent a carrier of most of our common contagious diseases, such as tuberculosis, influenza, and smallpox. To what extent the fly carries animal diseases is not known, but it is believed to be to a large extent responsible for the spread of anthrax, cholera, and hoof and mouth disease. It may also carry the eggs of worms.

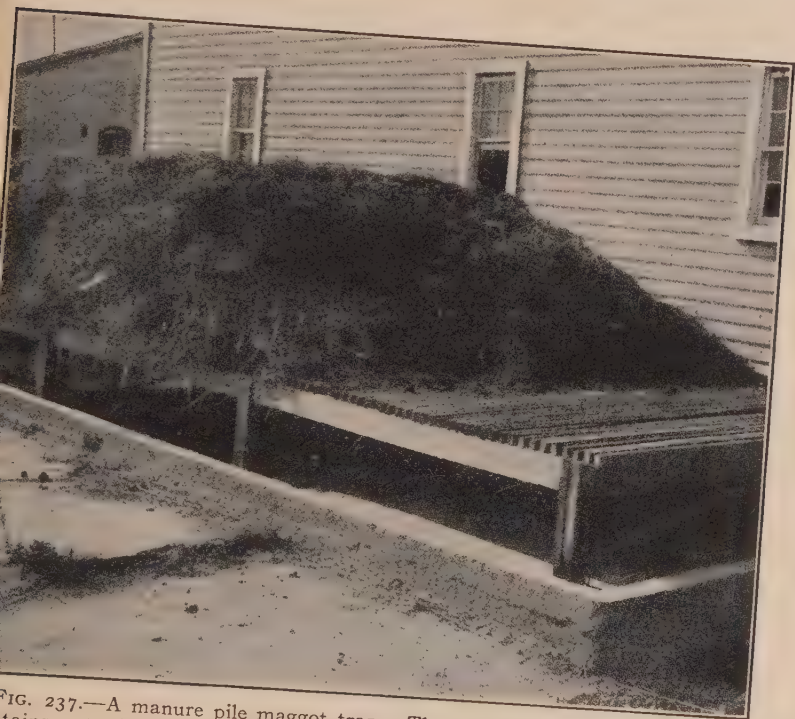


FIG. 237.—A manure pile maggot trap. The concrete bin beneath the pile contains water in which the maggots drown when they attempt to pupate in the manure. (U. S. Dept. of Agriculture.)

**FLY CONTROL.**—Since it is impossible to kill all flies, all measures must be of the nature of attempts to reduce their numbers. In our large cities much money is spent every year in efforts to reduce the number of flies to a minimum. It is the duty of teachers and parents to aid this movement in every possible way.

**Prevention of breeding** is the chief means of fighting flies. If there are no breeding places there will be no flies. Remove all slops, garbage, and manure once a week. Why once a week? Compel every one to connect with the sewer. In the country the manure may be put on the field daily and spread out to dry, or it may be kept in a tank or bin which is built over a concrete basin which contains water. Under normal conditions, when the larvæ pupate they burrow into the ground, but in this case they fall into the water and are drowned. This will destroy 99% of the fly larvæ. Have a more detailed report given on this subject from Entomology Bulletin No. 200, of the U. S. Department of Agriculture.

**Poisoning** may be done with formaldehyde solution. Put two teaspoonfuls of formalin in  $\frac{1}{4}$  pint of water. Flies require large quantities of water. They will drink this liquid, especially if none other is available, and die. *Keep the poison away from small children.*

**Other means of fighting flies** are the use of sticky flypaper and swatting. These are both good, but they do not get the fly until it is indoors. Traps of many kinds have been made. Flies have no intelligence and will enter a trap readily. Most any moist food is good bait, but fruit, honey, and vinegar have an odor and attract more than foods with little or no odor. Screens are necessary to keep out flies. It has been estimated that we spend \$12,500,000 annually for screens against flies and mosquitoes. If we spent one-half this much intelligently fighting them there would be very few of them, but if we ceased to fight for one year they would be as abundant as ever again. We must keep everlastingly at it.

### SUGGESTED PROJECTS FOR EARLY SPRING

Committees may examine the places in your city where food is sold, and estimate the number of flies. Is the food exposed? Are the meat-markets properly screened? Note.—Use proper diplomacy and courtesy in making this survey, but remember that whether you will or not you are fighting a lifelong battle with the fly, and it is a battle to the death. No quarter is ever given by either side.

**Community Project.**—Secure the lantern slide, or chart lecture, from the International Harvester Co., Chicago, and invite the public out to an educational lecture on the fly.

**Committee Project.**—Select two members of the class to go to the City Health Officer with a letter of indorsement from the teacher, and request him to give the

class a talk on some timely subject relating to the fly. He will be greatly encouraged in his work if he knows that the schools are with him.

**Editorial Project.**—Can a volunteer committee be pledged to get some information in regard to the relation of flies to manure piles into the city press?

**Civic Projects.**—If the fly can not find horse manure it will lay its eggs in other manure, garbage, or slops. Are there any cow, horse, or goat stables in your city? Are they kept in a sanitary condition? Are the hen coops kept clean? Is the garbage properly cared for? How should it be cared for? Are all residences connected with the sewer? Appoint committees to make this survey thoroughly if it takes a week.

**Review Questions.**—Were flies always known to be harmful? What new knowledge has brought about our campaigns against the fly? Give the life history of the fly. Describe the fly's foot. How may bacteria be carried in the food of the fly? How may bacteria be carried by fly-specks? What diseases may be carried by flies? Do you think it is possible to exterminate flies? Why? How may we prevent flies from breeding? How is fly poison made? Discuss some other means of fighting flies. How is the manure pile maggot trap made?

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## UNIT VIII. PROBLEMS IN ECONOMIC BIOLOGY

Surely we can derive little pleasure from the study of such biological subjects as weeds, rats, ticks, and potato beetles; but life is not all pleasure. We must have knowledge, if we are to continue in the pleasures which we have. If we did not know how to fight the potato beetle, we would not have the pleasure of eating potatoes, for there would be none to eat. This may sound commonplace, but if you wish to know the value of potatoes, cease to eat them for a month; then when they are served to you in your favorite way, you will appreciate the successful fight which scientists have made against, not only the potato beetle, but all other pests which would rob us of our food and clothing.

Examples of losses due to weed and insect pests are often surprising to those who learn of them for the first time. In the National Forest in the Black Hills, a flea beetle destroyed a billion feet of lumber. You probably have little idea how many houses that lumber might have built. The cotton-boll weevil destroys from twenty-five to fifty million dollars worth of cotton annually.

The value of our agricultural crops is now considerably over ten billion dollars. If we estimate the losses due to insects at only one-tenth of the total value, the price which they exact of the farmers every year amounts to over a billion dollars. This amount of money, if it could be saved, would build three Panama Canals, rebuild all of the colleges and universities in the United States, or rebuild all of the buildings destroyed by fire in the entire country in four years.



## PROBLEM 1. WHAT HARM DO WEEDS DO, AND HOW MAY WE FIGHT THEM?

**General Questions.**—What is a weed? What special advantages do weeds have over other plants? In what ways do weeds affect crops? What is a good example of a parasitic weed? How do weeds with a bad smell or taste do harm? What harm may poisonous weeds do? How may weed seed cause loss? How may we avoid losses from weeds?

*A weed is a plant which is an enemy to some crop* is a good answer to the question, "What is a weed?"; but we must interpret the word *crop* very liberally, for the dandelion growing on a lawn is a weed, yet we do not ordinarily think of lawn grass as a crop. Another way of defining a weed is to say that it is a plant growing where it is not wanted. Red clover, horse-radish, rye, and Johnson grass may be valuable crops or weeds depending upon whether they are planted, or grow where they are not desired.

A weed, in order to live, must possess the power to grow in spite of the efforts of man to destroy it. They are especially adapted in various ways to live in the places where they are found. We may list some of the qualifications of weeds which enable them to succeed in spite of our best efforts to kill them.

1. Weeds produce many seeds. (Tumbleweeds, grasses.)
2. They often have efficient means of reproduction from roots and underground stems, or from runners. (Canadian thistle.)
3. They frequently have excellent means of seed dispersal. (Dandelion, burs, tumbleweed.)
4. They have an extensive root system. (Grasses, sunflower.)
5. They are able to grow rapidly, although they may be growing in poor soil. (Cocklebur, sunflower, wild lettuce.)
6. They may shade other plants to prevent competition. (Sunflower, cocklebur, burdock.)
7. They have a tolerance to shade when young, to drought in summer, and to frost in early spring. (Compass plant, dock, grass.)
8. They are frequently perennials and live where they have become established for many years. (Goldenrod, dock, horse-radish.)

9. They all have great ability to withstand plant diseases, and usually are able to successfully resist insect attacks.

10. They may be poisonous, or of a bad taste or smell, to avoid being eaten by insects and animals. (Fennel, wild onions, poison-ivy.)

11. A few of them live as parasites and avoid having to obtain food in the usual way. (Dodder.)

12. Many weed seeds have great vitality. They are able to live long under adverse conditions. (Wild mustard, ragweed.)

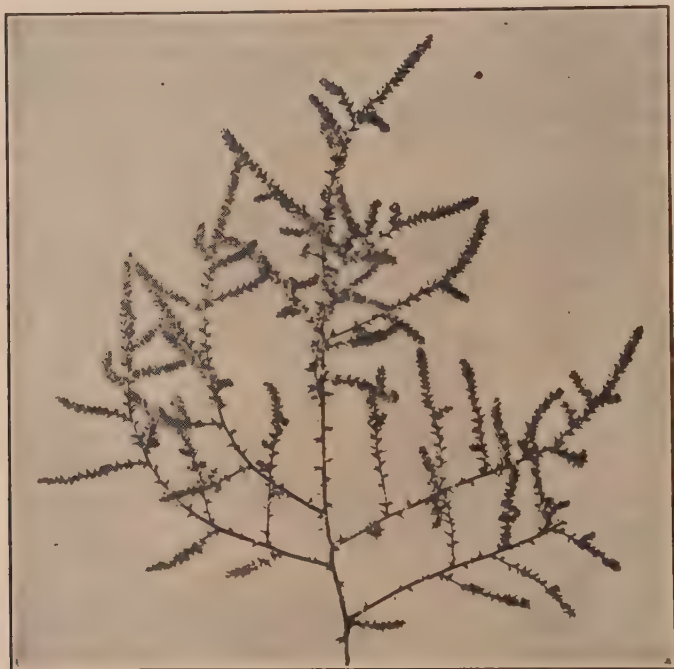


FIG. 238.—A spray of tumbleweed. The blossoms are so small that they can not be seen. There is a flower in the axil of each scale-like leaf. This plant is frequently called the Russian thistle because its leaves resemble the spines of thistles, but it is not a thistle.

**Damage Done by Weeds.**—Some crops are entirely ruined by them, and all crops are interfered with more or less. It has been estimated that in spite of the best efforts of the farmer his losses due to weeds are at least a dollar an acre and may be much greater.

*The three general ways in which practically all weeds affect crops are by shading, and by robbing the plants of soil water and mineral salts.*

The sunflower, jimson-weed, burdock, and cocklebur have very broad leaves, grow quickly, and starve out other plants which compete with them. Because weeds grow so rapidly, they require



FIG. 239.—The broad leaves of the sunflower prevent smaller plants which grow beneath it from getting sufficient sunlight for their existence.

great quantities of salts and moisture from the soil. The more they get the less there is for the cultivated crops. (See Fig. 239.)

*The special means by which weeds do damage are many. We will consider only the most important cases.*

**1. Parasitic Weeds.**—Clover dodder grows from a seed and sends a root into the ground. As it grows its stem twines around the clover

plants and sends root-like processes into their stems. It soon loses its root and becomes a parasite living wholly on the clover. Dodder is an example of a parasitic weed, of which we have but few, as yet, in North America. (See Fig. 240.)

**2. Unsavory Weeds.**—When cows eat wild onions, or fennel, the oils contained in the stems and leaves of these plants pass into the milk



FIG. 240.—A part of a dodder vine growing on a plant stem. Note the blossoms, also the processes which penetrate the stem for food near the center of the figure. (*Jenkins.*)

giving it a disagreeable taste and rendering it unfit for butter making or use in the manufacture of condensed milk. (See Fig. 241.)

**3. Poisonous Weeds.**—Live stock raisers are often troubled by the larkspurs, loco weeds, hemlocks, and laurels. Stock often eat these weeds when vegetation is scarce. Colts, calves, and lambs are more apt to be affected than adult animals. The juices of poison-ivy, poison-oak, and poison-sumach cause blisters to form in the skin of people who come in contact with them. Refer to Farmer's Bulletin No. 86 and to Professional Papers Nos. 125 and 365, if a more complete study of this topic is desired. (See Fig. 242.)

4. **Weeds may be hosts to parasites.** Several wild grasses harbor the Hessian fly over winter. In the spring it leaves the grass and attacks the wheat. (See Farmer's Bulletin No. 640, *The Hessian Fly*.) (Fig. 243.)



FIG. 241.—The jimson-weed, an example of a weed which is well protected. It has a very bad odor, a bitter taste, is poisonous, and its seed capsule (*b*) is covered with prickles. It thrives around barns because stock will not eat it, and other weeds which might compete with it are eaten. (*U. S. Dept. of Agriculture.*)

Wheat rust is harbored by the barberry and several wild grasses. The wheat-rust fungus lives on the barberry over winter and leaves this plant in the form of spores in the early summer to attack the



growing wheat. Write to the U. S. Department of Agriculture for literature on the relation of the barberry to wheat rust.

**Survey.**—Appoint committees to cover your city and see if there are any tall-bush barberries in the community. If there are they should be removed (Fig. 244). Does your state have a law requiring



FIG. 242.—Poison-ivy. Note the seed capsules and that the leaves are three parted. (*U. S. Dept. of Agriculture.*)

this to be done? How can you find out? One way is to appoint a committee to consult some public spirited lawyer.

**5. Burs** are produced by the burdock, cocklebur, and sand-bur. Such burs accumulate in the manes and tails of horses and in the tails of cattle. They are very difficult to remove. They reduce



FIG. 243.—The life history of the Hessian fly. This insect pest lives over winter on wild grasses as well as on winter wheat. (U. S. Bureau of Entomology.)



FIG. 244.—Digging up the barberry which harbors wheat rust. It must be taken out roots and all or it will grow again. (*U. S. Dept. of Agriculture.*)

the value of wool if they occur in sheep pastures. Sheep may lose much wool by rubbing against spiny and thorny plants which pull it out.

6. **Weed seed** is often mixed with the seed of clover and other crops. About fifty different kinds of weed seed may be found in clover seed, and about twenty-five in timothy seed. If weed seed is planted with the clover it will be all the more numerous the next



FIG. 245.—Mixture of weed seeds commonly found in low-grade alsike clover seed: *a*, alsike clover; *b*, white clover; *c*, red clover; *d*, yellow trefoil; *e*, Canada thistle; *f*, dock; *g*, sorrel; *h*, buckhorn; *i*, rat-tail plantain; *k*, lamb's-quarters; *l*, shepherd's-purse; *m*, mayweed; *n*, scentless camomile; *o*, white campion; *p*, night-flowering catch-fly; *q*, oxeye daisy; *r*, small-fruited false flax; *s*, cinquefoil; *t*, two kinds of peppergrass; *u*, catnip; *v*, timothy; *x*, chickweed; *y*, Canada bluegrass; *z*, clover dodder; *1*, mouse-ear chickweed; *2*, knot-grass; *3*, tumbling amaranth; *4*, rough amaranth; *5*, heal-all; *6*, lady's-thumb. (Enlarged.) (U. S. Dept. of Agriculture.)

year. Many farmers plant much of their weed crop each year, with the manure which is put on the land.

7. **Weeds damage the appearance of farms, parks, and lawns.** Dandelions are common nuisances on lawns, and jimson-weeds are well known for their presence around barnyards.

8. **The pollen of ragweed is believed to be the main cause of hay fever.** Some other weeds cause rashes and irritations. Thorns of cactus plants and thistles may cause injury also.

**9. Weeds interfere with the work of the farmer.** Their presence in the shocks checks the drying of grain after it is cut. They increase the labor of thrashing. Their presence in cured hay and straw decreases its value. Potatoes, beets, and carrots are removed from the ground with greater difficulty if weeds are present.

**The Solution of the Problem.**—We have made out quite an indictment against weeds. What are we going to do about it? Must we always have weeds? Perhaps we must, but we can do much to reduce their numbers. It is estimated that it cost \$75 per year to fight weeds on a 100 acre farm in Ontario. Must man always pay this toll to weeds? The future holds the answer to this question.

**Weed Control.**—Sheep eat weeds in preference to grass. They should be allowed to graze where they will kill weeds and not damage other crops.

Weeds may be sprayed with a prepared solution of copper sulphate which will kill some of them and not harm certain crops, such as grain.

All weed seed should be removed from grain before it is fed or it may be planted with the manure. Only clean seed should be planted.

Crop rotation is another way to fight weeds. Few weeds are able to grow among all crops. Many weeds, such as cockle and dodder, are peculiar to certain crops and can not live if rotation is practiced.

Fences should be taken out if possible, and roadsides should be mowed before the weeds go to seed. If they have gone to seed they should be cut, dried, and then burned.

Be an enthusiastic supporter of all reasonable projects which are aimed against the weed.

**Field Trip.**—Go out into the fields and gardens and gather as many different kinds of weeds as you can find. Write to the state department of Agriculture of Wisconsin, Minnesota, Michigan, and Ohio for their weed bulletins and look up the names of those which you have found. Classify them according to how many of the twelve characteristics they possess. Is your city a weedy city?

**Review Questions.**—Mention some ways in which weeds are well fitted to maintain themselves. What are some of the special advantages of the tumbleweed, sunflower, dodder, jimson-weed, poison-ivy? Outline the life history of the Hessian



fly and show how wild grasses may harbor it over winter so it may attack the wheat in spring. Why should the tall barberry be rooted up and destroyed? What are the three general ways in which nearly all weeds do damage? List on the blackboard the eight special ways in which weeds do damage and give examples of each case. Make another list on the board of the six ways mentioned in the text by which weeds may be controlled.

### References

Bulletins of the U. S. Dept. of Agriculture and of the various states may be had free. Write for lists of the latest bulletins. An excellent bulletin with colored plates may be had at cost from the Dept. of Agriculture, Ontario, Canada.

Georgia, *Manual of Weeds*, Macmillan Co.

### PROBLEM 2. HOW DO INSECTS DAMAGE CROPS?

**General Questions.**—How great is the damage done by insects? What is the first step in the solution of an insect problem? What is the story of the potato-beetle as an insect pest. What is the life history of the San Jose scale? How is it controlled? What is the life history of the white grub? How is it controlled?

**The Problem.**—Every crop has its insect pests. Some crops are attacked by more than fifty different kinds of insects. Some insects do very little harm, but others are always troublesome. The insects which do the most harm usually confine their attacks to a certain crop, but there are others, such as grasshoppers and army worms, which eat almost anything that is green. The Hessian fly destroyed \$100,000,000 worth of grain in a single year. Other years it may do little harm. Some seasons several insects which attack a certain crop may be abundant, in which case the loss is very great. For instance corn is attacked by chinch bugs, cut worms, white grubs, army worms, corn stalk borers, and corn ear worms. If several of these are abundant in one season there will be very little corn.

The people of the United States, through their state and national governments, pay out about \$25,000,000 each year for research and campaigns against insect pests. Whenever you have an insect problem it is your privilege to write your state, or the national,

department of agriculture for information and help. If the information which you seek is not known, and is important, research will be started to find out.

**The Solution.**—We have seen in the two previous studies that a knowledge of the life history of a fungus parasite is necessary in order to fight it successfully. It is just as necessary to know the life history of an insect. In this study we shall consider the life histories of three typical insect pests. The *potato-beetle* destroys the foliage of its host plant. The *San Jose scale insect* sucks plant juices. The *white grub* lives in the ground and destroys plant roots and underground stems. The life history and method of control of each is different, as we shall see.

The *potato-beetle* feeds on potato vines. The eggs are a golden-yellow color and are laid in masses on the under side of the leaves. The young are heavy-bodied, red grubs. They feed on the vines and do more damage than the adults. When the grubs are grown they dig into the ground to change into beetles. There are two broods each season. The adults winter over in the ground and emerge in the spring and begin laying eggs as soon as the potato plants come up.

This beetle appeared in fields between the Mississippi River and the Rocky Mountains about 1870. It formerly fed on the wild plants of the genus *Solanum* to which the potato belongs, but changed its food habits to take advantage of the more abundant domestic crop. It spread eastward rapidly and soon reached the eastern states. It was at that time feared that the potato could no longer be raised on a commercial scale. Some, remembering the Irish famine due to the blight, prophesied famine in America.

Until the potato-beetle appeared, the science of economic entomology (study of harmful and beneficial insects) did not exist. It was necessary to find some successful method of fighting the beetles or give up raising potatoes on a large scale. Many methods were tried and found to be useless, or of little value. Finally, Paris green was dusted over the leaves on which the insects were feeding. They could not avoid eating some of the poison and were killed.

The successful control of the potato-beetle by means of Paris green marked the beginning of man's scientific contest with insects for the

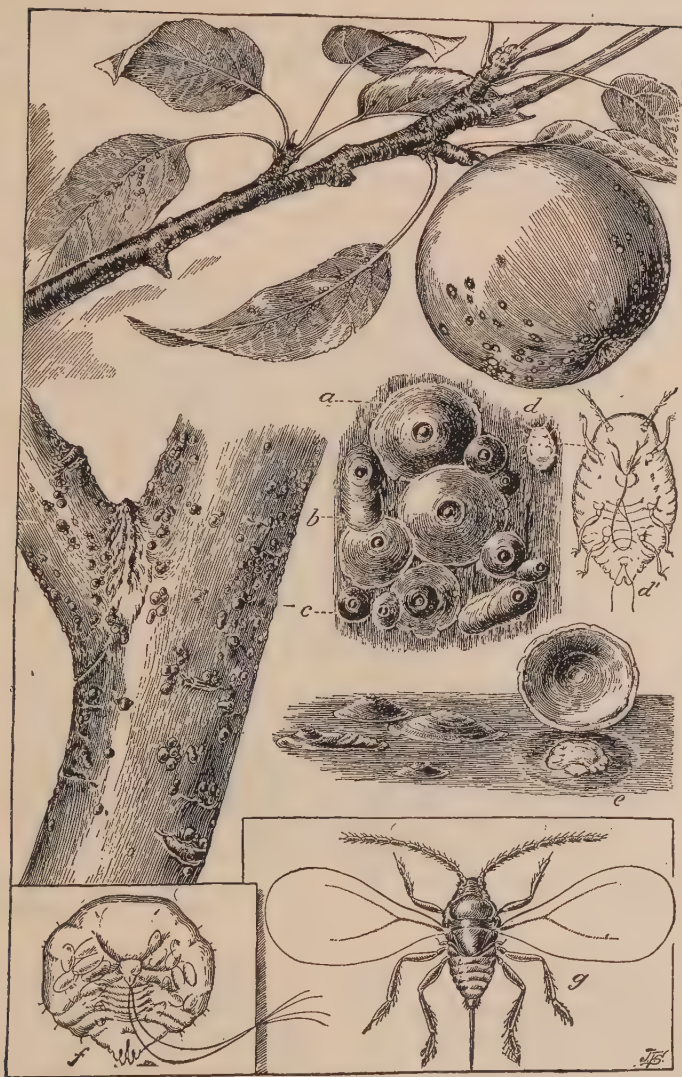


FIG. 246.—Life history of the San Jose scale. (U. S. Dept. of Agriculture.)

Above is an apple with the characteristic red spots which indicate the scales. To the left is a branch with scales on the bark. *a*, is an adult female scale; *b*, a young male. Note the difference in shape. *c*, young scales, sexes similar; *e*, side view of male and female scales, and a female scale lifted up to show the insect beneath. *d*, *d'*, young scale in the crawling stage; *f*, an enlarged female scale; *g*, a male with wings.

salvation of his crops. Before this time few European and Asiatic enemies of domestic plants had appeared in America, and our native species did little damage. What damage was done was usually attributed to Providence.

**The San Jose scale** (Pro. *Sän hōsā*) is an insect which is covered with a thin, flattened, conical scale. It has a sucking beak which it inserts into the bark of twigs or the skin of fruits and sucks out the



FIG. 247.—An apple tree which is dying because it is infested with the San Jose scale. This tree is a source of infestation to all apple trees in the vicinity and should be removed.

sap. It winters over in the form of young individuals which become adult and produce enormous numbers of young in the spring. The young crawl out from under the scale of the mother and wander over the tree for a time, then settle down and begin feeding. They grow rapidly and become mature in about thirty days. There may be from two to six generations in a summer depending upon the length of the season (Fig. 246).



Nearly a thousand kinds of scale insects have been discovered and named, but the San Jose scale does more damage than any other. It was first found near San Jose, California, and is believed to have come originally from China where it is found but does little damage; perhaps because it is held in check by its natural enemies, and because the native trees have developed a certain degree of immunity to it. In America it attacks many kinds of trees and is especially fatal to the peach. The number of peach trees in Michigan was reduced from 8,000,000 to 3,000,000. This was largely due to the ravages of the San Jose scale. Some trees were killed outright, others were so weakened that they died of the cold in winter. Apple trees usually die slowly and may linger for several years. (See Fig. 247.)

**Control.**—Scale insects can be controlled by spraying the trees in the spring, just before the buds swell, with lime-sulphur solution. If they are very numerous the tree may also be sprayed in the fall after the leaves have fallen. But for the discovery of a method of controlling the San Jose scale, and others of similar habits, it would be impossible to successfully raise peaches and apples in most parts of the United States.

Sprays have been made from petroleum products which have given good results in some localities. Because of the cheapness of these oils, and their initial successes, it is hoped that their use will be perfected. The chief difficulty with lime-sulphur is that the product of various manufacturers varies in effectiveness. It is not easily standardized.

**White grubs** are the larvæ of several species of beetles belonging to the genus *Lachnosterna*. The adults appear in the spring in great numbers and eat the foliage of various trees. The eggs are laid in the ground during the day. The grubs feed on the roots of various plants, but the normal food of the majority of them is grass roots, hence they commonly lay their eggs in hay fields and pastures. The grubs live in the soil through two summers and change to beetles in the second fall but remain in the ground until spring, making the life cycle three years.

White grubs are a bad pest to corn, potatoes, and strawberries. At times they seriously affect other crops, particularly timothy and



the small grains. Farmer's Bulletin No. 140 reports that in the worst infested areas it is not unusual to find from 40 to 60 grubs in a single hill of corn and estimates the annual loss due to these pests at not less than \$12,000,000.

**Control of the white grub** is not so simple as that of the potato-beetle and scale insects. It is possible to kill the adults by spraying the trees on which they feed, with a stomach poison, but it would be too expensive to spray groves and forests for this purpose.

The males may be attracted to lights at night in great numbers and killed by arranging a water tank for them to fall into. This would be more effective if the females could be caught also. Since



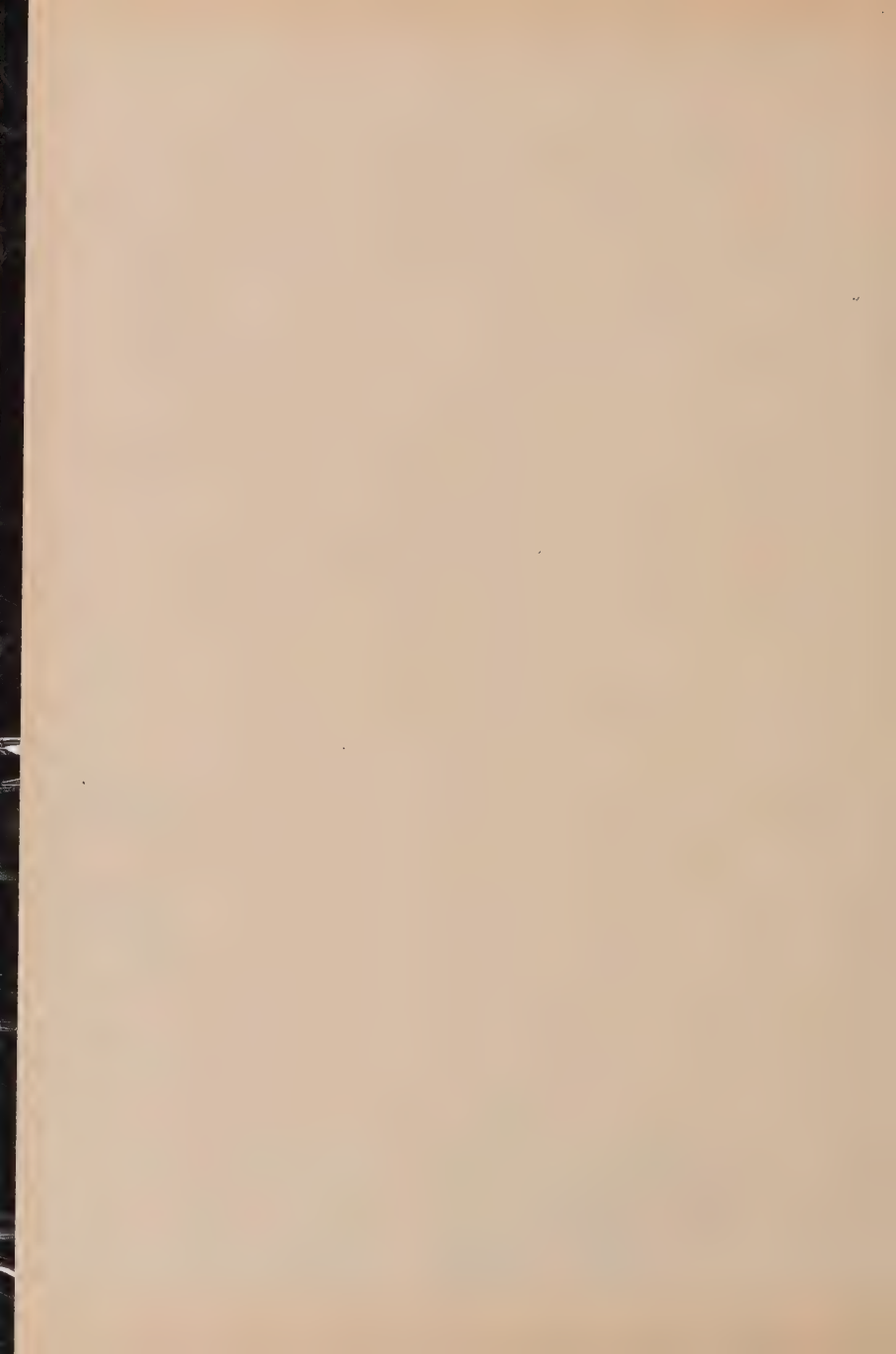
FIG. 248.—The white grub eating a potato.

the grubs feed beneath the ground it is impossible to reach them with a poison of any kind, but by knowing their life history it has been possible to work out measures for their control.

Since the eggs are laid in grass land, and the grubs feed two years, crops which they affect should not be planted on land which has been in grass until the second year; and since the grubs do not go beneath the plow-line in the fall until the end of September, the land should be fall-plowed before this time. This will kill many and expose many more to the attacks of birds. Chickens and pigs will eat large numbers of them if they are given the run of the fields.

**Review Questions.**—How can you obtain information about pests? What type of pest does each of the three insects described





in this study represent? What is the life history of the potato-beetle? How did it become a pest to the potato? In what way did the potato-beetle help to establish the science of economic insect study? How may potato-beetles be controlled? How does the San Jose scale damage plants? Where did it come from? How is it controlled? What is the life history of the white grub? What plants does it attack? Why is it difficult to fight? What measures of control may be taken against it?

### PROBLEM 3. HOW MAY INJURIOUS INSECTS BE CONTROLLED?

**General Questions.**—Into what two groups may harmful insects be divided? What is the method of poisoning each type? What are stomach poisons? What are contact poisons? How are repellents used against insect pests? How are plants fumigated? How does crop rotation help in the fight against insects? How does fall plowing help to control insects? How does cleanliness reduce the number of insect pests? How do weeds increase the number of some insect pests? How do birds and poultry aid us in our fight against insects? Of what value are fertilizers in reducing the damage done by insects? How do ichneumon-flies kill insects?

#### How may man save his crops from insect pests?

The poisons used to kill insects are of two kinds, depending upon the shape of the mouth-parts and the methods of feeding of the pests. Those which eat foliage can be fed a lead or copper poison which is called a *stomach poison*.

Those which feed by sucking the juice of plants can not be so killed because poisons placed on the outer surface of leaves, twigs, etc., will not be taken into their stomachs. These insects must be sprayed with a *contact poison* which is strong enough to kill them by coming into contact with their bodies. (See Fig. 250.)

**Stomach poisons** came into use with the discovery that Paris green would kill potato-beetles. Paris green may be used in the powdered form or it may be mixed with water and sprayed on the plant through a nozzle which throws a fine spray.

*Lead arsenate* is now used more than Paris green. It is not quite so powerful a poison, but it is cheaper and does not hurt the foliage

of plants as much as Paris green. It is now customary to use Bordeaux mixture with Paris green or lead arsenate. This combination spray will control both chewing insects and fungus diseases.

It has become customary to spray for the control of the codling moth, potato-beetle, plum curculio, and flea beetles. If time permits reports on the life history of each of these pests should be made by some member of the class. See the following bulletins of the Bureau of Entomology, U. S. Dept. of Agriculture: 41, 103, 19, and circulars Nos. 123, and 87.

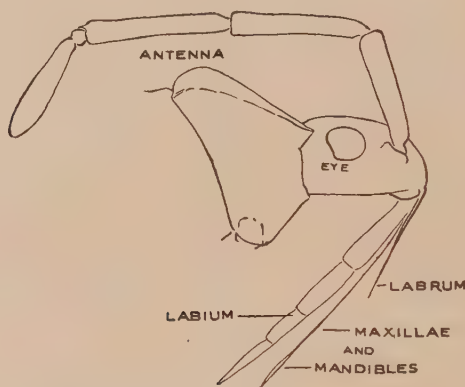


FIG. 250.—Mouth-parts of the piercing and sucking type from the squash bug. Note that the maxillæ and mandibles are united together to form a sucking tube.

**Contact poisons** are used chiefly against the various kinds of bugs and flies. We have mentioned the use of lime-sulphur in the control of scale insects. Soap solutions, kerosene emulsions, and nicotine solutions are the other forms most commonly used.

*Kerosene emulsion* may be made by dissolving  $\frac{1}{2}$  pound of hard soap in one gallon of water and adding two gallons of kerosene. This is the stock solution and must be diluted. The dilution varies from five to fifteen gallons of water to one of the stock solution according to use. Plants with delicate foliage can not withstand an application of a strong solution.



*Nicotine*, *soap*, and *lime-sulphur solutions* are on the market in concentrated form and may be diluted according to directions.

Aphids and leaf hoppers do damage to potatoes, fruits, berries, and vegetables. They often reduce the yield of potatoes to one-third of what it should be. They are controlled with difficulty by the use of kerosene emulsion. If possible, go on a field trip and observe or demonstrate the use of sprays.

**Repellents** are chemicals used to drive insects away. The best known repellent is moth balls, or naphthaline. Its odor drivee away clothes moths. Lime may be used to drive away the striped cucumber beetle. Tobacco dust is a repellent to the root maggots which attack cabbage, radish, turnips, and onions. Whitewash, containing various chemicals, is often used on tree trunks to drive away the egg-laying adults of borers.

**Fumigants** are poisons which can be vaporized. The ones in common use are carbon bisulphide, carbon tetrachloride, hydrocyanic acid gas, and the fumes of sulphur and tobacco. Ants may be destroyed by making a hole in the center of an ant hill with a stick, pouring in carbon bisulphide, and closing the top of the hole. The fumes will penetrate to all parts of the nest and will probably kill the queen. This will put an end to the colony.

Young fruit trees which are imported are usually fumigated to avoid the possibility of bringing in some foreign pest. Growing trees are sometimes covered with a tent and fumigated to kill all insects which they harbor. Warehouses and flour mills are sometimes fumigated by heating them to a high temperature to kill insects which live in stored food.

**Crop rotation** is resorted to to control insects which live in the ground and feed on the underground parts of plants, or against insects which do not travel great distances. We have mentioned its use in combating the white grub. Have a report given on the value of crop rotation to fertility of soils.

**Fall plowing** destroys many delicate insect larvæ and disturbs others so that they may be eaten by poultry, birds, or hogs. If the plowing is done late many will not get below the frost line before they are frozen. Fall plowing is of value against wireworms, white grubs, potato-beetles, grasshoppers, tomato worms, and ants.

**Removal of crop wastes and remnants** is of value in fighting the codling moth of the apple. The apple worm, which is the larva of the moth, may be found in the wind-fall apples. If they are allowed to lay on the ground the larvæ emerge, change to chrysalides, and become adult in time to lay eggs for the second brood before the main crop is ripe. The adults of several pests winter over in trash along fence rows, under leaves, and in brush piles.

**Weeds** harbor insects in various ways. If the expense is not too great it is a good plan to destroy all weeds. Assign reports on the



FIG. 251.—A pair of California quail. They are worth their weight in gold as destroyers of harmful insects and eaters of weed seed.

relation of the following insects to weeds: Hessian fly, potato-beetle, carrot caterpillar. See bulletins of the U. S. Department of Agriculture.

**Birds and poultry** are great destroyers of insects. Quail earn their weight in gold. They should be protected by the farmer, and should never be shot unless they become so numerous as to do damage to grain. The wise farmer does not permit quail shooting on his farm.

The black- and yellow-billed cuckoos eat woolly caterpillars in great quantities. Even crows and sparrows are man's friends when

an insect war is on. It is questionable whether the shooting of any wild birds, with the exception of four hawks, should be permitted. Most hawks are known to be highly beneficial (Fig. 326).

**Fertilizers** increase plant growth. In many cases the insect injury is done during the time when the plant is small. If it grows vigorously during this time it may survive an insect attack. This is of special importance in the case of wireworms, white grubs, cutworms, aphids, and the Hessian fly. Sometimes planting the crop a little early or a little late is of great value. Have a report given on fighting the Hessian fly by this method.



FIG. 252.—The black-billed cuckoo, destroyer of wooly caterpillars.

**Ichneumon-flies** (Fig. 253) and many other species of flies live as parasites on other insects. There is hardly a single species of insect which does not have them for its enemies. Their usual method of attack is to lay their eggs on, or in, the larva. As the young fly develops, it feeds on the juices of its host, finally killing it. But for these "friends of man" nearly all forms of insects which live on plants would be so numerous as to become pests.

*Nature maintains a balance among the number of living things.* If a species of insect is abundant this year, its ichneumon enemies

will be numerous also. The next season there will be very many ichneumons, and the abundant species of insect will be checked. In fact, the over-abundance of its enemies may nearly exterminate the insect pest, and it may do little harm for a few years.

**Laboratory Study.**—Study the mouth parts of a chewing insect,—such as a grasshopper, beetle, or caterpillar. Compare them with the sucking mouth parts of a bug. The squash bug, giant electric light bug, or cicada are good.



FIG. 253.—A cocoon of the lunar moth and an ichneumon-fly which emerged from it. The larva of the ichneumon-fly ate the chrysalis of the moth.

Begin building up a collection of injurious insects mounted by the students. Protect them from moth and beetle larvæ pests by spraying the specimens with bichloride of mercury solution. An atomizer makes a good spray instrument.

Make a field trip to study the use of sprays against insect pests.

**Suggested Individual Project.**—Investigate the life history of some insect pest and report what you have found to the class.

**Review Questions.**—How do the mouth-parts of sucking and chewing insects differ? What two poisons are frequently used against chewing insects? What poisons are frequently

used against sucking insects? What insects must be fought with repellents? What materials may be used to fumigate? What is crop rotation? Why are crop rotation and fall plowing used against insects which live in the ground only? How are wind-fallen apples related to the second brood of apple worms? What kind of insects does the cuckoo eat which are not eaten by other birds? Are any birds harmful? How does nature maintain a balance between all living things?

#### References

The best references on economic insects are the bulletins of the U. S. Department of Agriculture. Write for their catalogue of bulletins which are free and for sale. Those who wish may have their names on the mailing list to receive current announcements of new free bulletins as they are printed.

Reese, *Economic Zoology*, P. Blakiston's Son & Co.

Lochhead, *Economic Entomology*, P. Blakiston's Son & Co.

O'Kane, *Injurious Insects*, Macmillan Co.

Fernald, *Applied Entomology*, McGraw-Hill Book Co.

#### PROBLEM 4. WHAT IS THE ECONOMIC IMPORTANCE OF SPIDERS, MITES, AND TICKS?

**General Questions.**—How do spiders differ from insects? For what purposes do spiders make webs? Are spiders valuable? How do ticks and mites differ from spiders? How do ticks spread cattle fever? How does the red spider affect crops? How may we be free from chiggers? How do mites do harm?

Spiders and scorpions are related to insects and crayfish and are thought of as insects by many people, but they differ from both of these groups in some easily recognized particulars. The class ARACHNIDA belongs to the phylum ARTHROPODA which, it should be remembered, also contains the class INSECTA. The common arachnids are the spiders, scorpions, harvestmen, ticks, and mites. In these forms the head and thorax are closely united and form one structure. There are four pairs of legs. Spiders differ from insects in the particulars noted in the following table which should be worked out and put in the notebook of each student. It should be made out by each student from specimens and references. See the study on classification.



## LABORATORY INVESTIGATION

| Compare these parts | Class Insecta<br><i>Grasshopper</i> | Class Arachnida<br><i>Spider</i> |
|---------------------|-------------------------------------|----------------------------------|
| Body divisions..... |                                     |                                  |
| Legs.....           |                                     |                                  |
| Wings.....          |                                     |                                  |
| Mouth-parts.....    |                                     |                                  |
| Feelers.....        |                                     |                                  |
| Respiration.....    |                                     |                                  |

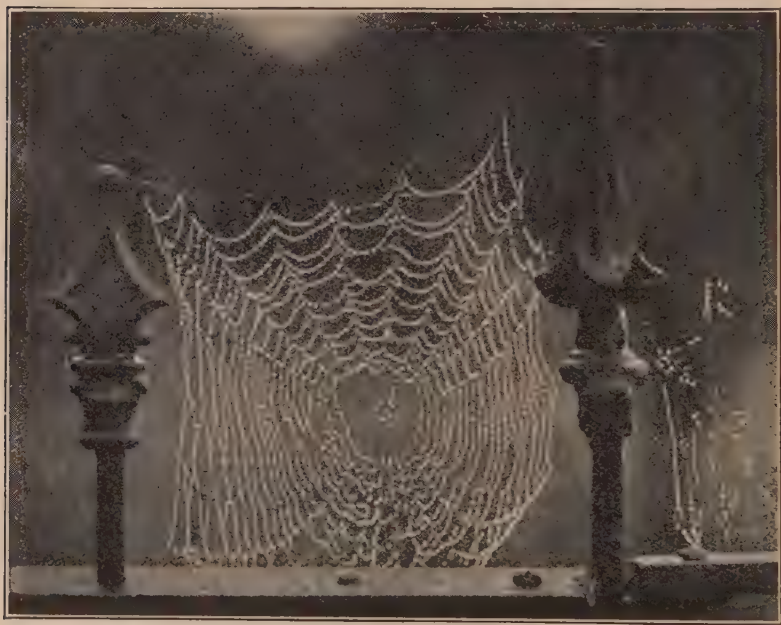


FIG. 254.—Dew on a spider web.

**Spider Webs.**—Perhaps the most interesting thing about spiders is their webs which are made from a fluid carried in their abdomens. It is allowed to emerge through minute openings called *spinnerets*. When the fluid comes in contact with the air it dries. The uses made of webs are numerous and varied. The web shown in the

picture was used to catch flying insects. The picture was taken on a very cloudy morning. Some spiders enclose their eggs in spider web, some line their burrows with it, some spin long webs and sail away before the wind. Nearly all spiders use the web as a safety line to avoid falling.

**Economic Importance.**—Spiders, harvestmen, and scorpions are, in general, beneficial. They do practically no harm at all and devour many harmful insects as well as some which are valuable; however, not all arachnids are beneficial. The ticks and mites are often very harmful.

We should be able to distinguish between spiders, ticks, and mites. Spiders may be large or small, but they are always very active, and have long legs. Ticks and mites are heavy bodied, have short legs, and are sluggish in action. Nearly all ticks, when fully grown, suck the blood of animals. When they are full of blood, they are very much bloated as is shown in the figure. Mites are usually very small and may live on plant juices or blood. They also become distended when filled, but never get so large as ticks. See the figure of the red spider, which is a mite. The figure is greatly enlarged.

Some ticks and mites carry disease germs, some are parasites on plants, some live in the water and are parasites on fishes, some cause scab and mange in domestic animals, and one causes the seven year itch in man.

**The Texas cattle-fever tick** inhabits the southern part of the United States and other warm countries. It attacks cattle and carries the germs of Texas cattle fever. This fever has caused an annual loss of \$100,000,000. The fever is caused by a protozoan (*Babesia bigemina*). If a tick attacks an animal which has the fever it will take the microbes into its body. It remains on its host until it is fully gorged with blood when it drops off and develops its eggs. It does not attack a second animal, therefore the disease is not transmitted by the tick direct; but its eggs harbor the germs and pass them on to the young ticks. When these attack an animal the germs are injected and the disease is transmitted. Prepare a diagram to illustrate the cycle. (See Fig. 255.)

**Control Measures.**—The disease is kept under partial control by the enforcement of a rigid quarantine against the shipment of southern cattle.



FIG. 255.—The life history of the cattle-fever tick. Enlarged. (*U. S. Dept. of Agriculture.*)

It has been found that by using a system of rotating pastures in such a way that the young ticks will starve for lack of animals to attack the disease can be checked. It is also possible to kill the

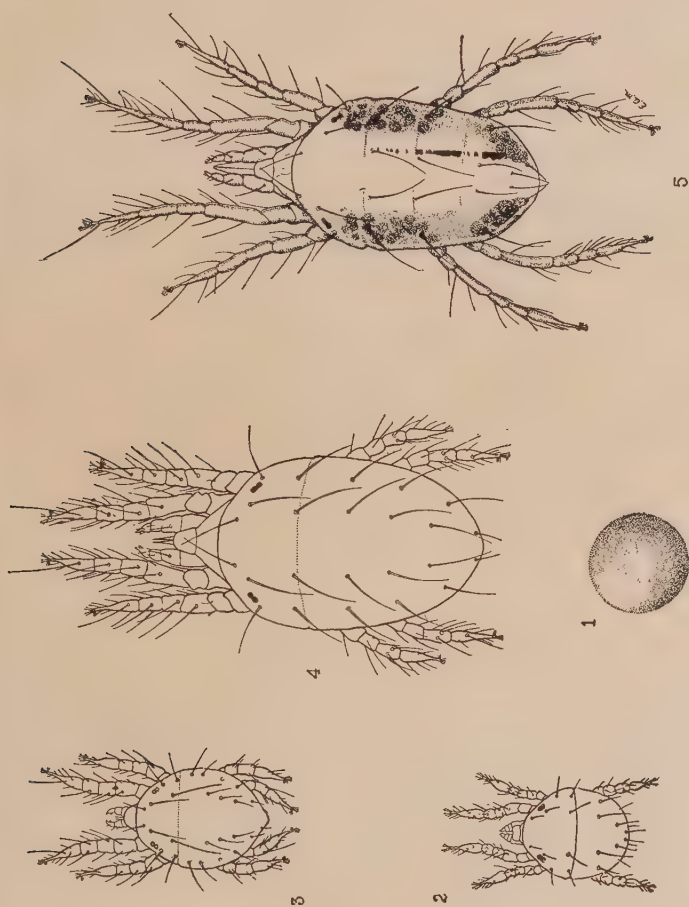


FIG. 256.—The life history of the red spider. 1, egg; 2, newly hatched larva; 3, second stage called the protonymph; 4, third stage called the deutonymph; 5, adult female. Enlarged. (U. S. Dept. of Agriculture.)

ticks by subjecting the cattle to a lime-sulphur dip. Southern cattle often have an attack of the fever when they are young, recover, and remain immune thereafter.

**The red spider** (Fig. 256) is a parasite of plants. It is bright red in color, very small, and belongs to the group of arachnids known as *mites*. It is known to attack 183 different species of plants in North America. About half of its host plants are domestic. It may do very serious damage to cotton, blackberries, tomatoes, beans, and peas. It is often confused with the class of fungus diseases called *rusts* because of its red color.

The red spider is a good example of a parasite which is harbored over winter by weeds. It can be controlled by crop rotation, destruction of weeds on which it winters, and the use of contact sprays.

**Harvest mites** (Fig. 257) are commonly known as *chiggers* throughout the central states. The adults are small red mites. The young



FIG. 257.—The harvest mites or "chiggers", the one with six legs is a larval form and the one with eight is an adult. (U. S. Dept. of Agriculture.)

are found on blades of grass where they wait for their host. They may infest most any animal with which they come in contact and do damage to dogs, cats, birds, cattle, horses, and man. They can be killed easily on man when they first attack by rubbing the affected parts of the body with a cloth moistened in strong alcohol.

**Itch mites** are arachnids which cause itch in man, scab in cattle, and mange in dogs. Nearly every animal, wild and domestic, is affected by one or more species of itch mite. Some cause scabs on the skin, and some dig in the skin and cause severe irritation. Some do great damage to domestic animals and are very difficult to control. Lime-sulphur dip is the remedy most often used, but some species require special treatment.



**Follicle mites** (Fig. 258) live in the hair follicles of many mammals. It is almost impossible to destroy them. One form may be partly responsible for pimples in the skin of man.

**The poultry mite** (Fig. 258) is found in hen coops. They conceal themselves during the day and attack the fowls at night. They often kill setting hens and are the worst and most abundant of all

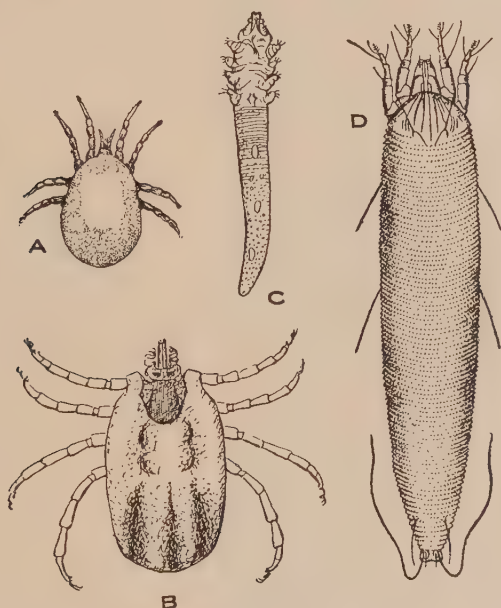


FIG. 258.—Some common arachnid pests. A, the poultry mite; B, the cattle tick; C, the follicle mite; D, the leaf blister mite of the pear and apple. (U. S. Dept. of Agriculture.)

poultry pests. They can be controlled with whitewash, lime-sulphur, or kerosene emulsion. Cleanliness and rigid sanitation will keep them out when once removed.

**Scorpions** (Fig. 259) are classified with the spiders. They differ from true spiders in that they have a large pair of pinchers like a crayfish, and their abdomen is extended more than is that of the spider. They are of little economic importance, and are not abundant in the temperate zone, being more common in the tropics.

**Centipeds** (Fig. 260) are many legged, long bodied animals belonging to the class MYRIAPODA. Refer to the study on classification and compare them with insects and spiders. The millipeds are also members of this class and have more legs than centipeds. Their names mean "hundred legs" and "thousand legs".



FIG. 259.

FIG. 259.—Photograph of a whip scorpion. The first pair of legs and the tail-bristle are used for feeling.

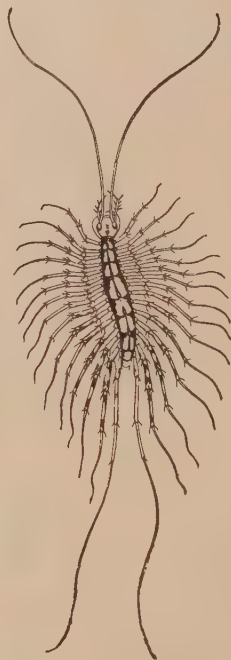


FIG. 260.

FIG. 260.—The house centipede, a harmless and beneficial inhabitant of our houses. It eats flies and other small insects. (*Marlatt, The House Centiped.*)

These animals are of very little economic importance, but we mention them here because of their relation to spiders and insects. Millipeds are vegetarians as a rule, and centipeds are nearly always eaters of flesh. They live on small insects for the most part. Neither of them is in any way harmful to man, although some of the large

tropical centipeds might inflict a slight wound if permitted to bite one.

**Suggested Project.**—Observe as many different kinds of spiders as possible and learn for what they use their webs. You will probably be surprised to note the many different forms used for catching prey, but this is only one of the many uses which spiders make of their webs. Make a list of them.

**Note to Teacher.**—Devote some time to a socialized recitation or round table discussion of spiders and their webs.

**Suggested Field Project.**—If the red spider is found in your community make a list of the plants on which it is found, and try to find out on what plants it passes the winter. Of what value is such information?

**Reports.**—If time permits, reports may be given on the Rocky Mountain spotted fever tick, the clover mite, and the sheep tick. Consult the latest Farmer's Bulletins from the U. S. Department of Agriculture. The sheep tick is an insect of the order DIPTERA which has lost its wings and has taken up a mode of life like that of the ticks.

**Laboratory Investigation.**—Make a table comparing the centipede and millipede with the spider as follows:

| Compare these parts | ARACHNIDA | MYRIAPODA |           |
|---------------------|-----------|-----------|-----------|
|                     | Spider    | Centipede | Millipede |
| Body divisions..... |           |           |           |
| Legs.....           |           |           |           |
| Eyes.....           |           |           |           |
| Feelers.....        |           |           |           |
| Respiration.....    |           |           |           |

**Review Questions.**—How do spiders differ from insects? How do spiders spin webs? For what do they use webs? Are spiders harmful? Compare ticks and mites. How does the tick cause cattle fever? How is Texas cattle fever controlled? How does the red spider do damage? Is it a spider? What are chiggers and how do we "cure" their bites? What evil effects are caused by itch mites? What animals are attacked by follicle mites? What is the poultry mite and how is it controlled? Compare centipeds with spiders and insects. Compare centipeds and millipeds.

## References

Bulletins of the U. S. Department of Agriculture.  
Emerton, *Common Spiders*, Ginn & Co.

## PROBLEM 5. WHY IS THE RAT AN ENEMY OF MANKIND?

**General Questions.**—What is the annual loss due to rats? Where do rats go in summer? Why is the rat the most wary of all animals? How do rats destroy food? How do rats destroy property? How do rats carry diseases? How do rats carry trichina? How do rats carry bacteria? What is the value of coöperation in fighting rats? How may we fight rats? Are cats valuable as destroyers of rats?

*"The most destructive animal in the world."* This is the statement of David E. Lantz of the Bureau of Biological Survey, U. S. Department of Agriculture. Lantz estimates that on the average each rat destroys \$2 worth of produce each year, and that the total annual loss is \$200,000,000 in the United States. It requires the labor of an army of 200,000 men to replace this loss. If half were represented by grain destroyed it would require 5,000,000 acres to produce it.

The rat inhabits every continent and most all islands. It crosses oceans, deserts, and mountain ranges.

Its numbers are controlled by the supply of food. When food is abundant rats multiply, and when there is no food they eat each other until the coming of spring. They seek the open fields in the country in summer and feed and multiply freely. In winter they enter barns and granaries where there is plenty. The rat may breed six to ten times a year and produce an average of ten young to the litter. At this rate how many rats will a pair produce in a year?

Because all rats do not seek the dwellings of man in the South it is, perhaps, impossible to get rid of them completely in North America. Therefore, the rat will continue to be an eternal enemy of our people. Man has fought the rat for centuries and has devised many ways of killing it. This long struggle has made the rat the most wary of all wild animals, and the most difficult to catch in a trap or to poison.

**THE INDICTMENT.**—In our case against the fly we found it guilty on but one count,—*it carries disease germs*; but we can make out

many counts against the rat. The only reason why flies kill more people than rats is that they are more numerous.

**1. Rats destroy food.** They eat all sorts of food that man does and garbage besides. They eat the standing grain in the field; the stored grain in bags, bins, or cribs; and the prepared food in stores and houses. They destroy growing ducks, pigeons, and chickens. One rat may destroy all of the young chickens on a farm in a single night. They have been known to attack grown hens when hungry. They destroy young birds and bird's eggs, and may even eat hen's eggs if they are left in the nest over night.

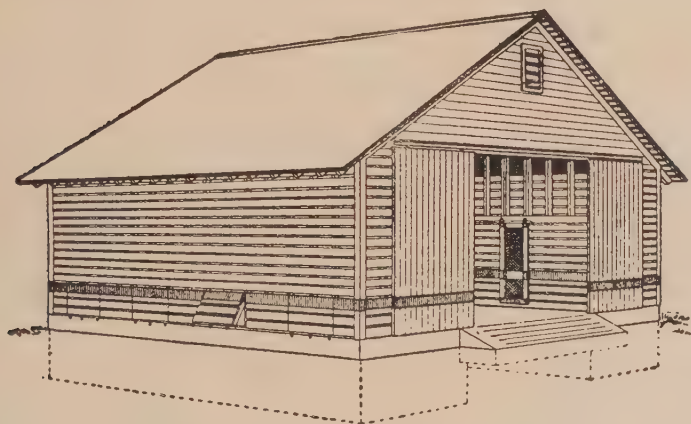


FIG. 261.—A rat proof corn crib with concrete foundation and a metal strip running all around to prevent rats from climbing up the sides. (*U. S. Dept. of Agriculture.*)

**2. Rats destroy property.** They gnaw holes in the floors of buildings and dig under foundations with their holes. They dig into the banks of drain ditches and cause them to fall in. They dig through levies permitting the water to run through and flood land. They gnaw lead pipes and flood buildings. They cause fires by gnawing matches. They carry food into buildings and leave it to decay, or they may die and decay between walls where they can not be removed. Besides all this the amount of money spent in making buildings rat proof is considerable.



**3. Rats carry bubonic plague.** In the epidemics of the fourteenth century which swept over Europe, it is estimated that 25,000,000 people were killed. One half of the population of Italy died of it. Grass grew in the streets of London, and corpses were left unburied when the "black death" ravaged it. This disease is constantly present in Asia, Africa, Australia, and South America. Outbreaks occurred in San Francisco, Seattle, and Hawaii in 1909, in Porto Rico in 1912, and in New Orleans in 1914. These were promptly suppressed by killing off all rats.

*Bubonic plague* is caused by a bacterium which is carried from one rat to another by fleas. It is primarily a rat's disease. When a rat dies the fleas leave it. If an infested flea should bite a person, the disease would be acquired. In exterminating the plague all animals which may be infested by the rat flea must be killed or quarantined. Cats, dogs, squirrels, mice, gophers, prairie dogs,—all must go.

The successful fight made by the United States Government against bubonic plague whenever it has made its appearance is one of the greatest achievements of biological science. Only 77 people died of it in San Francisco before it was stamped out. The difference between 77 and 25,000,000 deaths marks the triumph of modern science over medieval superstition. In the face of facts like these, who doubts the value of teaching biological science!

**4. The rat is the natural host of trichina.** We have discussed trichina in another study. When a rat dies, if there is a shortage of food, it is eaten by other rats. Also rats eat the dead bodies of other animals. For these reasons trichina are more often found in the bodies of rats than in any other animals.

**5. Rats carry bacteria on their feet and tails.** Of all homes the rat prefers a drain ditch to any other. They are excellent divers and swimmers. Rats which live in sewers come out at night and spread the germs of typhoid fever, cholera, and other intestinal diseases wherever they go.

Since the eggs of tapeworms, round worms, and hookworms are found in sewage they are carried by rats, but to what extent the rat is responsible for the spread of these diseases is not yet fully known.

**Coöperation.**—We have now found the rat to be guilty on five counts. The student may ask, "If this is all true, why do we permit

rats to live?" There are several reasons for their existence. They reproduce rapidly; they are wary of dogs, traps, and poisons; and the public does not realize how dangerous or numerous they are. In the solution of biology problems nothing is so important as coöperation. If we are ever to rid ourselves of rats, flies, and contagious diseases we must work together. An ordinance does little good if the public is not educated to its need and organized to aid in its enforcement. There will always be some who refuse to aid in campaigns for civic betterment. They must be made to feel the force of public opinion and do their part.

**RAT EXTERMINATION.**—After we have killed the last rat we must be ever on the watch for the first one to come into our city or barn-



FIG. 262.—A good type of trap for rats and mice. This is a mouse. In some places they do more damage than rats.

yard. Only by persistent effort and eternal vigilance can we keep our city free from rats, *but it can be done*.

1. **Starvation.**—If rats can be kept out of barns, basements, sewers and other places where they may find food in the winter in the north and central states they can be greatly reduced in numbers for there is little for them to eat in the fields.

2. **Poisons.**—The use of poison is seldom to be recommended. It causes suffering to the rat, the dead bodies give off bad odors, and valuable animals may be killed. Barium carbonate and arsenic are recommended by the U. S. Department of Agriculture as rat

poisons. Never use a phosphorous poison. It may cause fire. For methods of using poisons see Farmers' Bulletin No. 896.

**3. Traps.**—The boy who can outwit an old rat and secure him in a trap may well feel proud. Traps requiring bait, except cage traps, are not to be recommended for old rats.

*The focal method* of destroying vermin consists in attracting them to a certain place (a focus) and then destroying them. Feed your rats well every day for a time, then set a trap for them. They are wary of the scent of human beings and will usually avoid a trap that is freshly set or that is not buried. Keep your traps set all the time winter and summer. If you use a cage trap leave the door open and they will go in and out for food. Then close it and let them enter by the trap door.

**4. Cats very seldom kill rats.** Some are actually afraid of them. The tested rat catcher may be of some value, but traps are better.



FIG. 263.—A cat eating a bird. It is estimated that the average cat kills fifty birds a year. They very seldom kill rats. Cats do more harm than good.

*Cats catch birds, carry disease germs, leave bad odors, and harbor fleas and intestinal worms.* In fact, in some ways they are worse than rats. All stray cats should be destroyed by the city pound master, and all petted cats should be licensed the same as dogs.

*Hawks and owls* destroy large numbers of rodents (rats, mice, and gophers). They are much better than cats. Some snakes, as

the black snake, are great rodent destroyers. Nearly all hawks, owls, and snakes should be protected. Our original ideas about these animals must be revised. There are only four hawks which do more harm than good (Fig. 326); and among the snakes, only the poisonous ones, and probably the water snakes and garter snakes, are not beneficial.



FIG. 264.—A pile of rodent skulls found under an owl roost. Owls do not digest the bones of animals, but pass them out through the mouth after the flesh is digested. Owls should be protected. (*U. S. Dept. of Agriculture.*)

**Organization.**—"At New Burlington, Ohio, a rat hunt took place some years ago in which each of the two sides killed over 8,000 rats, the beaten party serving a banquet to the winners". (Lantz.) Have you enough enthusiasm to do something of this kind in your city? There is no better method of educating the general public to the facts of the rat problem.

**Other Pests.**—Space does not permit us to mention house mice, meadow mice, and gophers. If time permits they may be studied by assignments and reports, or their life history may be studied as a project by direct observation.

**Exercise.**—Make a diagram of the life cycle of the bubonic plague germs. Put some of the diagrams on the board and compare them in class.

**Suggested Project.**—Are any of the sewers or drains in your city infested with rats? Are there any cesspools so constructed that they may be entered by rats?

**Subject for Debate.**—Resolved that it is as great a civic necessity to license cats as to license dogs.

**Review Questions.**—What does Lantz say about the destructiveness of the rat? How fast do they multiply? Compare rats and flies as enemies of man. How many ways can you mention in which rats destroy food? Mention some ways in which rats destroy property. How is the rat related to the spread of bubonic plague? How is this disease controlled? How may we make buildings proof against rats? How is the rat related to trichina? What bacteria may rats carry from sewers? Is it a difficult matter to keep a city free from rats? Describe each of the five best means of destroying rats. Is it wise to keep cats to kill rats? How may hawks, owls, and blacksnakes do good? Will it be wise to start a rat exterminating campaign in your city? What other rodent pests are there?

#### References

Bulletins of the U. S. Department of Agriculture.



## UNIT IX. THE IMPROVEMENT OF LIFE

Our forefathers were not satisfied to leave the world as they found it. In all spheres of human activity we find that from decade to decade they made progress. The wonderful advantages which we enjoy to-day are a heritage from the people of the past.

In the days of savagery, domestic plants and animals were little different from the wild forms from which they were developed. They have been constantly improved until they are what they are to-day.

In the study of this unit we shall try to learn how life has been improved. We shall give special attention to the scientific methods which are used by plant and animal breeders to increase the value of our crops and useful animals. Finally, we shall study the laws of variation and heredity as they apply to plants, animals, and mankind with the hope that a knowledge of these laws may help us to improve ourselves and the next generation.

## STUDY I. THE STORY OF CORN

**General Questions.**—How does corn rank in importance with other grains? How does the United States rank with other nations as a producer of corn? How did corn originate as a domestic grain? How is corn improved by breeding?



FIG. 265.—At the time of pollination the silk is growing from the ear and the tassel is shedding pollen. (*Robbins.*)

**Corn** is the largest of all grains. It was not known to the old world until after the discovery of America. It was grown by the Indians of both North and South America. Several corn-like plants are found wild in the tropical regions of this continent, but it must be remembered in trying to find its ancestor that it is now vastly different from its original form. There is good evidence to show that it formerly bore both pollen and seed in the same flower cluster. Each grain was probably covered by a husk as are the grains of wheat and oats. A corn of this type has been developed (pod corn)



FIG. 266.—At the end of the season. The two flower clusters of sweet corn. At this season the tassel is dead and brittle.

(Fig. 267), and is grown largely as a curiosity. It is a common thing to find an ear in the tassel, or a tassel in the ear of corn as it grows in the field. Furthermore, corn is exceedingly variable and must be constantly selected to keep up the standard of any one breed. The common varieties of corn are shown in the illustration.

The United States produces over 70% of the world's supply of corn, nearly all of which is consumed within our borders, but more and more is being exported yearly. It is our most important stock

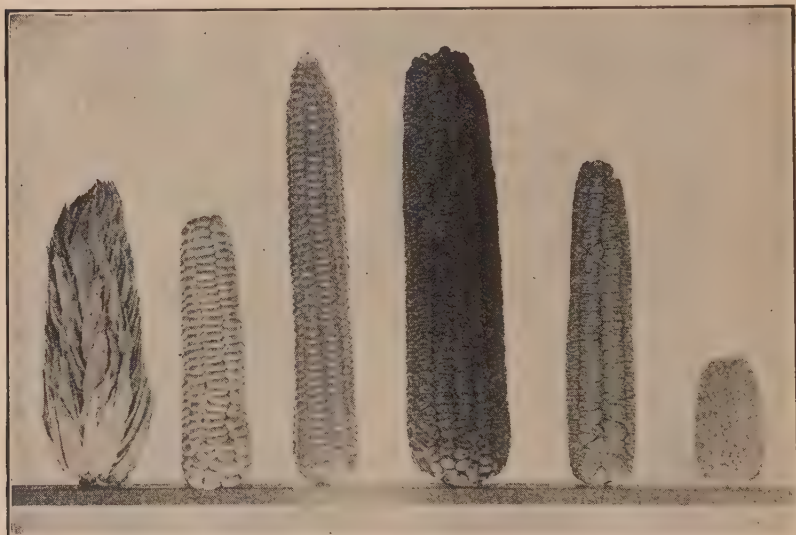


FIG. 267.—The six types of corn. From left to right,—pod corn, soft corn, flint corn, dent corn, sweet corn, pop corn.

food, and promises to become the greatest agricultural crop of the world. It is used by man in the form of cornmeal, glucose, starch, and breakfast foods, but will probably never replace wheat as the basis of flour. Its use as a food for dairy cattle in the form of ensilage is increasing the output of milk and butter per acre in nearly all sections of the country. Much of the corn raised in the central part of the United States is fed to hogs.

**Corn breeding** will serve as an example of the methods used in improving a plant that is extremely variable, cross-pollinates, and must be constantly selected to preserve a standard type.

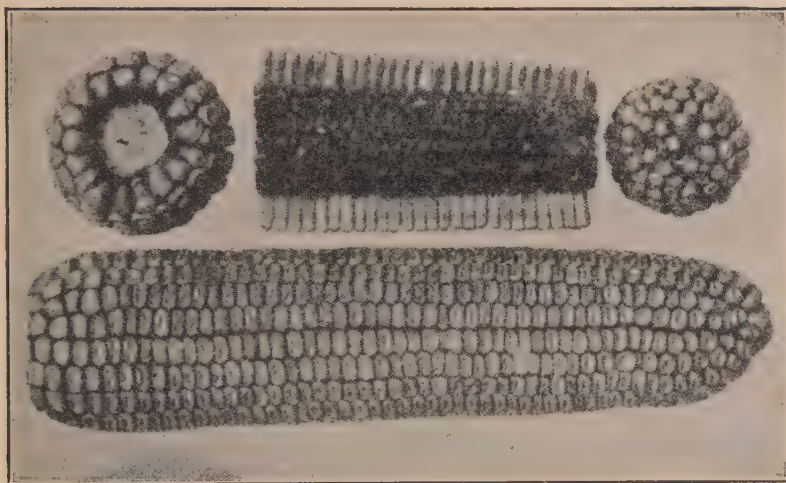


FIG. 268.—The characteristics of a well developed ear of corn. The butts and tips are well filled, the rows are straight, the cob is small, and the seeds are neither too long, too short, or too thick. (*U. S. Dept. of Agriculture.*)

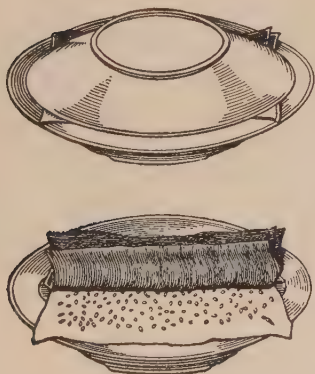


FIG. 269.

FIG. 269.—The plate tester for testing the germinating power of seeds on a small scale. The seeds are placed between two pieces of cloth or blotting paper and moistened. They are then placed between two plates to prevent drying out until they germinate. (*U. S. Dept. of Agriculture.*)



FIG. 270.

FIG. 270.—Variation in the shape of corn grains. Which shape will fill the space around the cob the more completely? (*Mich. Agr. Exp. Sta.*)



Localities differ as to soil, climate, drainage, etc., hence, corn that does well on one farm may not do well on another, even if the farms are located close together. For this reason, if the farmer can spare the time, he should breed his own seed corn from his own fields.

When the ears are mature the farmer should go through his field and choose the ears which conform to the type which he has selected to breed for. They should be chosen from hills containing three stalks, and from stalks bearing only one ear, under most circumstances. These ears should be carefully dried and sorted. Only the best should be used. In the spring, before planting time, some seed from each ear should be sprouted to test its germinating qualities. Those failing to show close to 100% in this test should be discarded.

A special plat of ground which is an average sample of the corn land on the farm should be planted with this choice seed. Each row should contain seed from only one ear. There is a common belief among corn breeders that if seed corn is pollinated by its own pollen its vigor will be reduced, hence, it is customary to cut the tassels from every other row, and save seed from the detasseled rows only. This insures cross-fertilization.

The best ears from the best rows should be planted in plats year after year, and the best rows constantly selected to produce the seed corn for the farm. It should be noted that the entire row is the unit in selecting, since it is the product of a single ear. Perhaps the worst danger confronting the ambitious corn breeder is to continuously produce larger and larger ears. Corn with large ears must have a longer growing season and does not ripen with certainty in the northern states. A safe, standard size should be bred for and those that exceed it in size must be discarded by breeders in the North. One of the most common causes of poor yields is the failure of the corn to ripen before frost.

It is not too much to say that the average number of bushels raised per acre in the United States can be doubled or even trebled by corn breeding. "It is difficult to realize that the average yield of corn in the United States in 1905, when the total production was the largest in our history, was only 28.8 bushels of shelled corn to the acre. It is still more surprising to know that the average production

per acre is practically the same to-day as it was forty years ago. In fact, the average yield per acre for the ten years from 1866 to 1875 was 26.7 bushels as compared with 25.2 bushels for the ten years from 1896 to 1905. There are several reasons for this, but the principal reason is gross carelessness in the use of seed of low vitality.



FIG. 271.—Common Wisconsin dent corn which has not been selected above, and improved Wisconsin seed corn below. "The uniformity and generally desirable characteristics have been secured by careful selection, curing, and testing through several years." (*College of Agriculture, Madison, Wis.*)

"During the last decade, corn breeders have achieved marked success in the production of improved types of corn, but unless the farmers throughout the United States take better care of their seed corn and test each ear separately, preparatory to planting, the

chances are that the average yield of corn per acre in the United States will not be materially increased." (*Farmers' Bulletin* No. 253, U. S. Department of Agriculture.)

The average acre contains 3,556 hills of corn. If each hill contains three stalks, and each stalk bears one  $8\frac{1}{2}$  inch ear, the yield will be 120 bushels per acre. If each hill produces two such ears the yield will be eighty bushels per acre. On good soil the yield should approximate eighty bushels per acre as a minimum, and no farmer should be satisfied with less. This is approximately three times the average yield for the country.

**Demonstration.**—Let two or more students volunteer to demonstrate before the class the method used in testing seed corn for germination. Get the latest bulletin on the subject from your State Department of Agriculture or from Washington, D. C., and use it for reference.

**Corn Judging.**—If time permits some good corn should be secured, and the students should be given an opportunity to judge it using the regulation score cards. They may be bought from the dealers in biological supplies.

**Note to Teacher.**—Little laboratory work can be done on this study and those following. Collections of the grains, fruits, and vegetables discussed should be secured and kept in the museum cases for demonstration purposes. It may be safely said that such a collection can never become complete. It should be added to from year to year.

**Field Trip.**—If possible observe some of the grains as they grow in the field. How and when are they planted? When harvested? What is the value of our grain crops in proportion to other crops?

**Review Questions.**—Where did corn grow originally? What do we suppose it was like? For what is corn used? Why is corn a good type to illustrate a method of improving plants? How are the best ears selected? How are the seeds tested? How are the seeds planted? Why are the tassels cut from every other row? What danger is there in trying to raise corn ears that are too long? What improvement may we hope for in the yield of corn per acre?

## STUDY 2. THE STORY OF WHEAT AND SOME OTHER GRAINS

**General Questions.**—How does wheat rank as a world crop? What kinds of wheat are there? Where did wheat come from originally? What ancient peoples raised wheat? How is wheat

improved by selection? What is the origin and importance of rice? What is the importance of rye? Where were oats grown originally?

Wheat is the staple grain crop of the people of Europe, Australia, and North and South America. Large quantities of it are raised and consumed in other parts of the world as well. It is the world's



FIG. 272.—Two forms of common wheat—beardless and bearded.

most important cereal, and will be raised in greater quantity when machinery for its cultivation becomes more widely used. The United States furnishes about a fifth of the world's supply.

Wheat belongs to the genus *Triticum* which contains at least seven cultivated species. Common wheat (*T. vulgare*) exists in many varieties, and new ones are constantly being brought forth. The varieties fall under such general groups as,—bearded, beardless,

red, white, black, winter, and spring wheats (Fig. 272). Its varieties have been modified to suit the soil and climate of most every agricultural region of the earth. The other six species are less known and may be described as follows (Fig. 273).



FIG. 273.—Six less common species of wheat. From left to right—Egyptian wheat, Durum wheat, Polish wheat, spelt, einkorn, emmer.

1. **Egyptian wheat** (*T. turgidum*) is a form with a branched head, but in spite of the fact that the head is larger, it does not yield so abundantly as common wheat because it can not grow so thickly. It is not adapted to growth in the United States, but has been much advertised; the claim being made that it originated from some wheat found in the pyramids of Egypt. This claim is false for wheat seed will not germinate after it is very old, ten or twelve years being the extreme limit.

2. **Hard wheat** (*T. durum*) is raised in southern Europe and to some extent in this country. It is a spring wheat with a long beard and a hard kernel.

3. **Polish wheat** (*T. polonicum*) is cultivated in eastern Europe.

4. **Spelt** (*T. spelta*) is a primitive form with a husk about each kernel.



5. **Einkorn** (*T. monococcum*) is a form with but one kernel in each spiklet on the sides of the head.

6. **Emmer** (*T. dicoccum*) resembles spelt but has a more compact head and is adapted to growth in dry regions. Besides these there are several wild grasses which belong to the genus *Triticum*, among which are **quack grass** (*T. repens*) and the **awned wheat grass** (*T. caninum*).

**The Origin of Wheat.**—When we consider the large number of species and varieties within the genus *Triticum*, it will be seen that the possibilities of the origin of wheat are numerous. However, the wild ancestor of wheat is not definitely known. A wild form is found in Asia Minor which could have developed into the cultivated form, but we can not be sure that it is the ancestor of wheat. The spelts are the simplest of the cultivated kinds and probably stand close to the original form. Most authorities give Mesopotamia as the place where in all probabilities the cultivation of wheat began. Good evidence is at hand to show that it was cultivated in China as much as 4,600 years ago, and that the lake dwellers planted it in Switzerland when Europe was emerging from the stone age. The Egyptians left wheat in the pyramids. It was probably brought to America by the early English settlers soon after 1600. It became the great bread-making cereal of the European and American continents early in the eighteenth century, when it surpassed barley.

**Wheat breeding** in addition to corn breeding may serve as an example of the method used in plant breeding by selection. In the early part of the nineteenth century Profesor La Gasca, of the University of Madrid, visited a wheat farmer named Le Couteur, living on the Isle of Jersey, near the coast of France. In looking over the wheat as it stood in the field, they discovered that twenty-three different varieties were growing together on the farm. As a result of this visit Le Couteur decided to try to improve his wheat by selecting the best heads from the best plants to produce his seed for planting. He succeeded in producing several good varieties, and is known as the first scientific breeder of wheat. The variety known as "Bellevue de Talavera" is still grown in France and England. The varieties which he established remained true to type for an indefinitely long time.

Some of the facts which are now known in regard to wheat must be taken into account by anyone who would try to improve an old variety or develop a new one.

1. Wheat that has been grown for many years without selection usually contains many varieties growing together in the same field. These differ in their physical appearance, not only, but in their commercial value as well. These varieties were called *elementary species* by de Vries. An elementary species must grow true to type when it is selected and grown separately.

2. Wheat is self-pollinated, and therefore, it grows true to type even though it has access to pollen from other varieties.

3. Wheat may be cross-pollinated artificially and new varieties established by this method. When so established wheat varieties are subject to the variations characteristic of hybrids in the second and third and future generations, but because of self-pollination they are more easily *fixed*. By "fixing" a type is meant selecting the type specimens until the plant breeds true with only slight variations. Wheat is relatively easily fixed, and has a strong tendency to remain so for many generations.

In selecting wheat a large number of the best kernels of the variety to be improved are chosen and planted in a plat of ground that has been set aside for the purpose. When the plants have developed, they are examined and only the best are selected. When the heads are ripe, only those from these choice plants are taken. The heads from each plant are put in separate bags and weighed. The next year the seed from the plants giving maximum yields are planted in individual rows; each row containing the seed from only one parent. This process is continued for four or five years, when the milling tests are run on the product; and if it makes good flour, the grain is sown in the usual way and put on the market.

The person who would improve wheat by selection should not expect too much. The very fact which makes it possible to quickly fix a type also makes it difficult to change a certain elementary species beyond a given limit without very long selection. If a distinctly new type is desired it is better to resort to hybridization and then selection. More will be said about this method as applied to other plants in another study.

Scientists in the employ of the Canadian Government completed the development of a new wheat in 1925 which has more resistance to wheat rust than any other species grown in Canada, and in addition is able to grow about 100 miles farther north than wheat was able to grow before. It is difficult to estimate, or conceive of, the many millions of dollars of wealth which this new wheat will add to



FIG. 274.--Breeding plots of grain which has been cross-pollinated. (*Minn. State Agricultural Exp. Sta.*)

the commonwealth of Canada. This is but one example of the improvements which are being made from time to time in our domestic plants.

**Rice** was cultivated in China as early as 2000 B.C. It is the staple grain food of the people of eastern Asia, and is the principal cereal food of two-thirds of the human race. It still grows wild in the marshes of Cochin China, and has been modified by man but little since its domestication. Being a marsh plant, man has not

destroyed its native growing places and forced the original type into extinction as he has in the case of many of our domestic plants. Rice probably was domesticated first by the Chinese. It spread through India to Babylon and Syria, and appeared in Egypt more than a thousand years after it was introduced into Babylon. It was grown in Italy in 1468. It came to the United States in 1694. A



FIG. 275.—Three common grains. From left to right—oats, rye, rice.

ship from Madagascar entered a South Carolina port in distress, and a bag of rice was left to one of the residents. Rice is now grown in considerable quantity in the southern states. Because of its great value as a food and the ease with which it is prepared for the table, it will, in all probability, be grown much more extensively when its cultivation is better understood throughout the South.

**Rye** (*Secale cereale*) is a new plant among the grains. No name is found for it in the ancient Semetic, Sanskrit, or Chinese languages. It was unknown to the ancient Greeks and Egyptians. It easily escapes and grows wild, showing that it has not been extensively modified by man. Several wild forms are found growing in south-eastern Europe and western Asia, and this is believed to be the place of its origin. It is more hardy than wheat, and is raised on poor soil or in northern countries where wheat does not thrive.

**Oats** (*Avena sativa*) was not known to the ancient Hebrews or Egyptians, but was cultivated by the Greeks and Romans. It is the staple horse-food of the civilized world today, and in the form of rolled oats is a very important food of man; about 1,000,000 bushels being used in this way each year. The total annual oat crop of the United States is approximately 1,000,000,000 bushels, and is 25% of the world's supply. It is not known where oats were cultivated for the first time, but wild oats grow in many parts of the world. Several closely related forms of variable appearance are found in North America. *Avena fatua* is strikingly like the tame oat, and is a bad weed in the spring wheat fields of the Northwest. Plant breeders in England have crossed a wild oat from eastern Asia on the cultivated oat with a view to improving it. Oats readily grow wild and may maintain themselves for several years.

**Review Questions.**—For what is wheat used? Do you know how spring wheat differs from winter wheat? What grain was used in bread-making before wheat was brought to Europe? Who was the first scientific breeder of wheat? How did he proceed? What is meant by "growing true to type"? What is meant by self-pollination? What is meant by "fixing a type"? How is wheat selected and planted with a view to its improvement? What advantages are possessed by the new Canadian wheat? How were rice, rye, and oats domesticated?

### STUDY 3. THE ORIGIN AND IMPROVEMENT OF VEGETABLES

**General Questions.**—What vegetables have been developed from the wild cabbage? Where did beets originate? How were sugar beets developed? How did we come to have the tomato as a vegetable? How did Europeans obtain the potato?





FIG. 276.—The wild cabbage (A) and the horticultural varieties which have been developed from it. B, broccoli; C, kale; D, kohl-rabi; E, brussels sprouts; F, cabbage; G, cauliflower. What parts of each of these are eaten? (*Gager.*)

How are potatoes improved? How are plants improved by selection? How are plants improved by hybridization?

How did man get his vegetables?

The cabbage grows wild in the south of England and Ireland. It is also found at various places in the northwestern part of continental Europe. Although it has been raised in many parts of the world for some centuries, it was not known to the ancients. The cabbage is raised in a great many varieties, but the most interesting thing about its breeding is its many relatives. It belongs to the genus *Brassica* which is native to Europe and temperate Asia. *B. alba* is the common mustard, *B. campestris* is the rutabaga and turnip, *B. napus* is rape, and *B. oleracea* is the cabbage. Kohl-rabi, cauliflower, kale, and Brussels sprouts also belong to the group and have probably developed from *B. oleracea*. All of the above forms are very closely related, and we would not have to go very far back in time to find the common ancestor of all of them.

The beet (*Beta vulgaris*) still grows wild in the Canary Islands, all through the Mediterranean region, and eastward. In the red form it is used for its root. In the white form the root is small, and it is used as chard. A giant, red type is called the mangel and is used as a stock food. The most remarkable of all beets is the white sugar beet.

The Germans wished to become independent of the tropics for their supply of sugar and experimented with carrots and beets to see if they could be used for that purpose. The carrot was dropped because of its slow response to selection. At first the beet contained but 3% or 4% of sugar. An entire field may now average over 14%, and individual specimens may be found which average 25%. The sugar beet is extremely variable in sugar content and must be continuously selected to keep it up to standard.

**Beet Sugar.**—The development of the sugar beet has made it possible for temperate countries to produce sugar which is exactly like that which is made from sugar cane, and is one of the remarkable scientific achievements of the past century. The beet sugar industry began in the United States about 1830. In 1890 the production of beet sugar had risen to 7,748,000 pounds, and in 1909 it totaled 1,024,938,000 pounds.

The tomato is a berry, but since it is grown in the vegetable garden we will consider it here. This plant is a newcomer among our domestic species. It is an American plant and probably originated



FIG. 277.—Chard, a form of beet with a small root and large leaf stems which are eaten. (*Robbins.*)

in Peru from where it was taken to Spain. The Europeans raised it in their gardens as an ornamental plant, and supposed it to be poisonous, because most plants in the night-shade family (*SOLANACEÆ*) to which it belongs are dangerous. This belief delayed its

popular use for some time. It has been a common garden plant only within the last hundred years. It lends itself readily to improvement and exists in many varieties. The canning of tomatoes and making them into soups and catsup has become a great industry within the past quarter century.



FIG. 278.—Two well-shaped tomatoes. There are fewer berries in a cluster than in the wild form.

**The potato** is also an American plant. Several closely related species are found throughout tropical America. De Candolle\* sums up a lengthy discussion as follows:—

“1. The potato is still wild in Chili, in a form which is still seen in our cultivated plants.

“2. It is very doubtful whether its natural home extends to Peru and New Granada (Columbia).

“3. Its cultivation was diffused before the discovery of America from Chili to New Granada.

\* *Origin of Cultivated Plants*, D. Appleton & Co.

"4. It was introduced, probably in the latter half of the sixteenth century, into that part of the United States now known as Virginia and North Carolina.

"5. It was imported into Europe between 1580 and 1585, first by the Spaniards, and afterwards by the English, at the time of Raleigh's voyages to Virginia."

It was cultivated extensively in Ireland soon after its introduction, and this has given it its name. It is the staple food of the Irish peasantry today. Next to wheat, it is the most important food of the western world. At the time of the American Revolution but two kinds of potatoes were raised in England, a white and a red variety.

New kinds are obtained by planting seed from the berries which grow on the vines, and resemble small, yellow tomatoes. It has been so extensively improved that most varieties have lost the ability to produce seed and are propagated solely by planting the tubers. We now have many varieties of both red and white potatoes and can have as many as we wish, for the potato is easily modified by breeding.

It should be interesting to note here that the potato and tomato are very closely related. They have been cross-pollinated and one grafted upon the other. When a tomato is grafted upon a potato both fruit and tubers may be found on the same plant. When a potato is grafted upon a tomato the tubers may be produced above ground from the base of the potato stem.

**Potato breeding** will serve as an example of the method used to breed plants by hybridization. The Rev. C. E. Goodrich of Utica, N. Y., is the father of potato breeding in the United States. The urge for his work was the great damage done by potato blight in both this country and Europe, which caused almost total failures of the crops. (See p. 299.) His aim was mainly to raise a blight-resistant variety by breeding from wild ones of South America. He secured several varieties from the American consul at Panama, which he supposed came from Chili and Peru. In 1853 a seedling from one of these plants known as the Rough Purple Chili was introduced into cultivation. Goodrich continued his work for several years, and between the years 1849 and 1856 he raised 8,400 seedlings.

In 1870 the Early Ohio, which is perhaps the most extensively raised potato in the United States, was grown by Alfred Rees. It is a third generation seedling of the Rough Purple Chili of Goodrich.



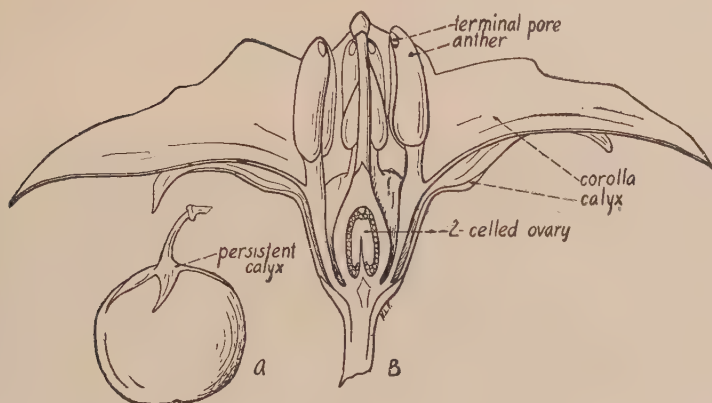


FIG. 279.—Drawing of the potato blossom and a berry to show the parts of the flower and its relation to the fruit. Grains of pollen are shed through the terminal pores directly on the pistil in self-pollination. (Robbins.)



FIG. 280.—Removal of stamens of a potato flower. *A*, before removal. Note the large stamens surrounding the pistil. *B*, the stamens removed and their stumps showing at the base of the pistil. (U. S. Dept. of Agriculture.)

Another third generation seedling of the same ancestor is the Burbank potato which was the first valuable plant product given to the world by Luther Burbank.

Potatoes seldom produce any seed. This is a characteristic of many plants which have been long domesticated and which are not propagated from seed. When potato seeds are produced they develop in small "potato balls" which resemble small tomatoes. The plants grown from potato seed are extremely variable because of the fact that nearly all domestic potatoes are hybrids and have not been fixed to breed true from seed.

In hybridizing potatoes to secure new types the stamens are removed from the flower to be cross-pollinated when it is a bud, and just before it opens. This is easily done by pushing the petals apart and breaking off the filaments at their base with a sharp pointed forceps.

In one or two days the flower opens and is ready to be pollinated. This is done by picking a flower from the plant chosen to serve as the male parent, and dusting out its pollen on the thumb-nail, from where it is transferred to the pistil of the flower which has had its stamens removed, by simply touching the stigma with the pollen.

In hybridization experiments, it is customary to keep the pollinated flower covered with a bag both before and after pollination to prevent any other pollen from getting to it; but in the case of potatoes, since they are self-pollinated, and their pollen is not extensively carried by insects, this is probably an unnecessary precaution. Of course only those potatoes which produce seeds can be used in this way in breeding experiments, and even these may not set very many seed balls when artificially pollinated; but some seedless varieties produce fertile pollen which can be used to obtain hybrids with kinds which do form seeds.

The seeds are carefully dried and saved until planting time. They should be planted early in a greenhouse or hotbed and later transplanted to a bed especially prepared for them. The tubers which are formed the first year may be few and small, but if they have good shape and are free from defects they may be saved and planted the next year, when their value will be apparent. By far the great majority of the tubers raised from seeds are found to be valueless,

but in one case in a thousand something of real worth may be produced.

If any of these hybrids which show merit produce seeds they should be saved and planted. Certain of these hybrids may be cross-



FIG. 281.—Two views of potato flowers showing how they grow. The ones above have some flowers in the proper stage for pollination. The ones below have been pollinated, and the ones which were too young or too old have been cut away. (*U. S. Dept. of Agriculture.*)

pollinated, and, thus, by continued hybridizing and selection the desired type may finally be achieved.

### How are plants improved by hybridization?

When an entirely new type of plant or a new combination of characters is desired by plant breeders it is customary to resort to hybridization. Varieties which possess some of the characters wanted are secured, if possible, and are crossbred. If the plant is one which is propagated by vegetative methods a type is easily preserved when once it is obtained, since grafting, slipping, or planting roots or tubers continue its life from year to year; but if it is raised from seed each year the hybrids will vary and an extensive process of selection must be resorted to to fix the type.

The very extensive work of Luther Burbank was based more largely on hybridization as a means of producing great variations and new combinations of characters to select from than upon any other method.

**Selection** in plant breeding has for its object (1) the improvement of the plant from generation to generation, (2) the fixing or maintaining of a type when once obtained, or (3) the elimination of undesirable stock which is mixed with the form which is being selected; and consists in choosing certain individuals from among many to serve as the parents of the next generation.

**Review Questions.**—Where does the cabbage grow wild? Name and describe the forms which have been developed from the wild beet. How was the sugar beet produced from the red beet? How important is the beet sugar industry? Where did the tomato grow wild? Where did the potato come from? Why is it called the Irish potato? Discuss its relationship to the potato. Who started potato breeding in the United States? What other names may be mentioned among the early potato breeders? How are potato seeds obtained? How are potatoes hybridized? Is it easy to get new and better kinds of potatoes from seeds? How are plants improved by hybridizing? How did Burbank produce the many new kinds of plants for which he became famous? For what three aims are plants selected?

#### STUDY 4. THE ORIGIN AND VALUE OF CULTIVATED FRUITS

**General Questions.**—What new fruits have been cultivated in the southern states? What are some of the wild fruits which



may be cultivated? Where were apples grown first? How are they improved? What ancient peoples are known to have grown the plum? What was the probable origin of the peach? How do European grapes differ from American grapes? How were grapes domesticated in North America?

How did man get his cultivated fruits?

Although man has domesticated many fine fruits, he has by no means exhausted the possibilities of what can be done in this field.



FIG. 282.—A branch bearing four fine persimmons.

The *banana*, *orange*, *lemon*, and *pineapple* have but recently become staple crops of the southern states; and the *date*, *fig*, and *olive* are becoming popular with fruit growers in the same region. Among our wild fruits which show great promise if brought under cultivation are the *persimmon*, *papaw*, *elderberry*, and *black haw*. Some attempt has been made to improve these and others of our native fruits, and some day they will be grown in commercial orchards as are apples and cherries. An excellent variety of the persimmon has been developed in China and is now grown in our southern states.





FIG. 283.—Variation among persimmons. These two persimmons are from different trees. Each represents the average size of the fruit on the tree from which it came. If there is this much variation in nature, is it not reasonable to believe that it can be made to vary still more under cultivation; and that some day we shall have a fine domestic persimmon? Hybridization with the Chinese persimmon may aid in this development.



FIG. 284.—The black haw, a fruit with a fine flavor and worthy of the attention of the plant breeder.

The *blackberry*, *strawberry*, *raspberry*, and *cranberry* have already been greatly improved. So many varieties of the first three have been produced that no matter how particular one's taste may be, a color, form, or flavor may be found to suit his fancy.



FIG. 285.—A hybrid blueberry grown by the U. S. Dept. of Agriculture. This cluster was  $3\frac{3}{4}$  in. in diam. Blueberries, cranberries, and huckleberries all belong to the genus *Vaccinium*.

The *huckleberry* has been improved but little, but has shown great promise of improvement under domestication. It varies considerably in the wild state. The *blueberry* is a variety which is now under cultivation. In your walks through the swamps, be on the watch

for exceptionally fine plants. You may be the discoverer of a new huckleberry.

**The apple** is our most important fruit. It is grown in a greater number of varieties and throughout a wider range of territory than any other fruit except the plum. Most fruits are luxuries, but the apple is almost a necessity in the diet of North Americans. It keeps better and has a wider range of uses than any other fruit. Make a list of the uses of the apple.

Both the common apple and the crabapple were domesticated in Europe and taken to America by the early settlers. We have several fine species of native, wild crabapples, but little has been done with them in breeding. The Indians made some use of them, but when the white men came they adopted the sweet apple and planted it in orchards. Some of the old Indian orchards of New York are still growing.

The apple was probably domesticated more than once in prehistoric times. It still grows wild in Europe except in the extreme north. As is the case with most domestic fruits, it does not breed true from seed, and when a new type is obtained it must be perpetuated by grafting. For this reason but little permanent progress was made in apple breeding until after grafting was understood. However, the apple will grow from cuttings which produce apples true to type.

**The plum** was domesticated by the Chinese in prehistoric times, and many good varieties were produced. The Latins raised many plums, probably from one of the many native European species. When the Europeans came to America they brought the plum with them and established it in the northeastern part of the United States, but the European plum did not do well in the South, and in this region the native plums were domesticated. So many kinds grow wild in North America that it has as yet been impossible to properly classify them. Wight in *Bulletin* No. 179, U. S. Dept. of Agriculture lists 23 species. Others have listed many more. The same author in *Bulletin* No. 172 lists 673 different kinds of plums which have originated from the 23 native American species. Only four of these have come from the states east of Michigan and north of Maryland. Most all of them were produced in the states in the

Mississippi basin. Iowa holds the record with 179 kinds to her credit.

Burbank cross-pollinated various American, European, and Asiatic plums and produced some of the best plums grown anywhere in the world. Most of these are grown in California. America easily leads the world in the quality and variety of the plums which she has produced.

**The peach** probably came from Persia. It is not known to grow wild in a native condition anywhere in the world. It is closely

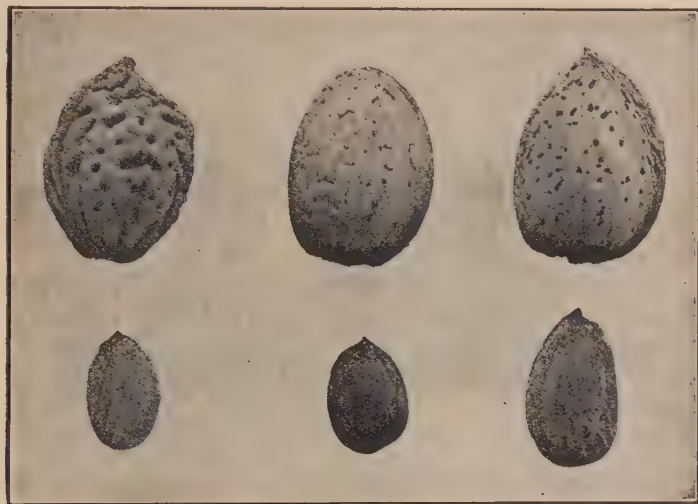


FIG. 286.—Stones of peaches and almonds arranged for comparison. On the left is a peach stone and a seed below; in the middle is the hard shelled, bitter almond; and on the right is the soft shelled almond.

related to the almond with which it can be cross-pollinated and on which it can be grafted. The almond is variable in the wild state and sometimes produces varieties approaching a poor peach in the quality of the pulp; furthermore, they both probably came from the same locality. For these reasons it is believed that the peach never grew wild but was developed from the almond.

In 1900 Michigan led all of the states of the Union in peach production with a total of over 8,000,000 trees. The peach can not stand

cold winters, and in 1910—due to cold and the ravages of the San Jose scale—the number of trees had been reduced to less than 3,000,000; and Georgia had taken the lead with over 10,600,000 trees, followed closely by Texas with over 9,700,000 trees. California stood third with over 7,800,000. This indicates that the peach is more successfully grown in the South than in the North; however,



FIG. 287.—One of the American wild grapes from which all of the domesticated grapes of the eastern United States have sprung.

hardy varieties of it can be grown in any state in the union, but not with certainty in some of the northern states.

The *nectarine* is a smooth skinned variety of the peach, and the *apricot* is a hairy skinned variety of the plum. The nectarine often develops from the peach, but the apricot is a definite variety of the plum and probably originated in China.



**The grape** has been cultivated since prehistoric times. It grows wild in the part of Asia south of the Caucasus Mountains, and probably spread both east and west from this region. De Candolle,\* writing in 1882, said that perhaps 2,000 varieties under domestication had been described, and many more have been developed since.

When the Europeans came to America they found that their grape would not grow here because it was unable to withstand diseases which it acquired from the native American species. Our native species were immune to the harmful effects of these diseases. At first it was a great disappointment to them, but they soon took to the native American forms of which Bailey lists 22 distinct species and thirteen varieties which grow wild. All of the juicy grapes are of American origin, and those with thick meat have been introduced from Europe. The European grapes are grown in California but not east of the Rocky Mountains to any extent.

**The Catawba grape** was found growing wild in North Carolina in 1842. The **Concord** was produced by Ephraim Bull at Concord, Massachusetts. The following is a quotation from him, written on a tablet marking the original vine which is still alive.

*"I looked about to see what I could see among our wildings. The next best thing to do was to find the best and earliest grape for seed and this I found in an accidental seedling at the foot of the hill. The crop was abundant, ripe in August, and of a very good quality for a wild grape. I sowed the seed in the autumn of 1843. Among them the Concord was the only one worth saving."*

Other forms have been found in a similar manner, and from these other types have been developed.

**Review Questions.**—What tropical fruits are now grown in the southern states? What prospect is there for the development of a domestic persimmon from the wild one? What berries are now cultivated? How does the apple compare with other fruits in value? Why is grafting necessary in the production of better fruits? What opportunity did our wild plums afford for improvement? What work did Burbank do with plums? Compare the peach and the almond. Why do we believe that the

\* *Origin of Cultivated Plants*, D. Appleton and Co.

almond is the ancestor of the peach? What are nectarines and apricots? Where do peaches grow the most successfully? Why do we not raise European grapes in the eastern part of North America? How was the Concord grape produced?

#### STUDY 5. THE DEVELOPMENT AND IMPORTANCE OF DOMESTIC ANIMALS

**General Questions.**—What animals were the probable ancestors of the dog? For what has man used dogs? What was the origin of the horse? What wild relatives has the horse? What two kinds of cattle have been domesticated? From what forms did each probably descend? What was the original home of sheep? Where were goats probably domesticated? What was the probable ancestor of the hog? What is the present economic importance of each of the animals named? How were birds domesticated?

**How did man get his domestic animals?**

**The Dog.**—Although man has domesticated many plants, he has brought under his control comparatively few animals. Perhaps the first animal to be domesticated by primitive man was the dog. It crosses readily with all wolves, the jackal, and the coyote; and has been interbred with these wild forms many times. The fox resembles the dog; but it is not one of its progenitors. The dogs of the Eskimos are very much like the wolf, and so were the dogs of the Indians.

In Europe the breeding of dogs reached a high development; and such types as the Scotch collie, foxhound, greyhound, bloodhound, and bulldog were developed. All of them differ very much from their ancestor, the wolf. In fact, they all differ more from each other than does the Eskimo dog from the wolf. It is a remarkable fact that wolves which have been domesticated often learn to bark like a dog, and drop the habit of barking and assume the howl again upon becoming wild.

The dog is not so essential to man now as in former times. Primitive man used him extensively in hunting and as an article of food. The Eskimos use the dog as a beast of burden to draw their sledges in the snow where the horse can not live. Shepherds and cattle



FIG. 288.—Eight kinds of dogs all developed from the wolf and its near relatives. Note the great differences in these dogs. (Romanes.)

raisers use the dog in herding; but the great distinction which the dog holds over all other domestic animals is that he has been a companion to man from the time when man was a savage until the present day. No other animal, not even the horse, has equaled the dog as a friend of man.

**The horse** was probably domesticated in Asia. The *tarpan* is a wild horse found on the steppes of Tartary and eastward to central Asia. It is certainly a horse, but whether it is the ancestor of the domestic horse or whether it is feral (escaped from domestication) has not been settled.

The first historical record of the horse comes from Assyria. It shows the rider mounted on a horse which is led by a servant. It seems a rather tame exercise when compared with following the hounds in England or cattle herding on our western plains. The Arabians rode the camel before they did the horse, and the Egyptians probably got their horses from the Assyrians at about the time of the close of the reign of the shepherd kings (1800 or 1900 B. C.).

The nearest relatives of the horse are the *Asiatic* and *African asses*, the *zebra*, and the *quagga*. The horse breeds with all of these, but the product of the cross is sterile. There is no proven case of a hybrid horse giving birth to young. The mule is the product of crossing the female horse and the male ass. It lives longer, is healthier, stronger, and will stand more rough usage than the horse.

**The wild ass** of Abyssinia was domesticated by the ancient Egyptians. It is very fleet of foot—outrunning the fastest horses, and in general characteristics far superior to the domestic form, which is the only plant or animal known which has failed to improve under domestication. The ass has never become popular in America. Asses which have become wild are numerous in our western mountains and deserts, but they have not regained the speed of their African and Asiatic ancestors.

**Cattle** were domesticated by the people of southern Asia in prehistoric times.

**Asiatic cattle**, which are called *zebus* (Fig. 289), differ from ours in having a hump on the shoulders and in being smaller in size. They are not found wild, but several forms, such as the *banteng*, *yak*, and *water buffalo*, are still abundant in the wild state. It is possible



that the Asiatic cattle have descended from some of these forms. The yak and water buffalo have been domesticated but have been changed so little that they become wild if allowed to escape.

**European cattle** have descended from the wild cattle of that country. The wild ancestor is extinct except in herds in hunting parks. In one of these parks they are known to have been confined previous to 1220. They are of a dirty white color with black muzzles, ears,



FIG. 289.—A zebu bull, imported from India. This is an exceptionally fine specimen. (*B. H. Hunnicutt in the Journal of Heredity.*)

and the switch of the tail. The lower portions of the legs may be brown or black. They are about the size of our Jersey cattle, which they resemble more than any other breed.

**Most American breeds of cattle** are of English parentage and are, therefore, descendants of the "park cattle". The cattle raised in America may be divided into two classes: those bred for beef and





FIG. 290.—The banteng, probable ancestor of zebu cattle. (*Bureau of Agriculture, Manila.*)



FIG. 291.—A cattalo. This is a hybrid between a bison and an Aberdeen-Angus cow. (*M. M. Boyd, Journal of Heredity.*)

those bred for dairy products. The beef cattle are heavy and hardy but give little milk.

The **American bison** has been crossed with domestic beef cattle with a view to improving the type in hardiness. The cross is called



FIG. 292.—Male and female of a fine type of wild sheep. Note what a superb specimen the male is as compared with a fat and woolly domestic type. This is the mountain sheep of Alaska, a sheep of the bighorn type. (*U. S. Dept. of Agriculture.*)

a “cattalo”. The zebu also crosses readily on the European type, and the two forms have been extensively interbred in Italy and Brazil. The zebu hybrid can withstand the heat of the tropics much better than common cattle.

**The sheep** has been domesticated since an early date and has more wild relatives than any domestic animal except the pig. In fact, there are so many wild sheep, especially in Asia, that it is impossible to say from what form it originated. It is probable that sheep, like



FIG. 293. A good type of male Angora goat. His fleece has grown five months since the last shearing. (*U. D. Dept. of Agriculture.*)

cattle, have more than one wild ancestor. They have been raised by man for milk, wool, and mutton.

The handsomest wild sheep in the world is the bighorn of the Rocky Mountains (Fig. 292); however, it has not contributed to the development of the domestic sheep; for the English settlers brought

sheep from England at an early date, and the sheep raising industry was well established before the western part of the country was developed.

Most wild sheep have horns, and the fact that they frequently occur in domestic breeds as sports is an example of *reversion*—i.e., the occasional appearance of an ancestral character which has otherwise been reduced by breeding.

**The goat**, like the sheep, still has several living wild relatives. They are found from the Pyrenees of Spain to the central plateau of Asia. Domestic goats come from several sources and are named after the place of their origin. Some of them are: the Egyptian goat, the Sudan goat, the Syrian goat, the Kashmir goat from the hair of which Cashmir shawls are made, and the Angora goat. The Angora goat comes from Angora in Asia Minor and was brought to the United States in 1849 by Dr. James B. Davis. More than 1,000,000 Angoras are now raised for their hair, which is called *mohair*, in the southern and western part of the United States.

Goats are also raised for their mutton and milk. In some parts of Europe and Asia the goat still furnishes the greater part of the milk used by the population. Goat's milk is richer than cow's milk but has a strong taste.

**The hog** is an animal of great economic importance in America. We are the greatest hog raisers of any nation in the world. Two types are raised—the bacon hog and the lard hog. Many more of the latter are produced than of the former, because it fattens faster and more cheaply and gets heavier than the bacon type. Discuss in class the relation of hog raising to the corn crop. What states are the greatest producers of corn? Of hogs? In the Southwest many hogs are raised on alfalfa and fattened on corn.

The hog was raised by the Chinese in prehistoric times and probably sprung from some of the wild pigs of that country. The Indian wild boar of southeastern Asia is very similar to the domestic pig and may be its original ancestor. When the hog reached Europe it was freely interbred with the European wild boar which is now almost extinct except in some of the hunting preserves of Germany. We are reasonably certain that the blood of more than one wild form has contributed to the development of the domestic pig.



**Domestic Birds.**—The most important domestic bird is the *chicken*. It is kept for its flesh, eggs, and feathers by nearly all peoples, and has been bred to conform to many standards of perfection. Its ancestor was the *jungle fowl* of southern Asia.

The *dove* or pigeon was bred from the *rock dove* of southern Europe and Asia. It rivals the chicken in variety of forms and colors. It is raised for its attractiveness, its flesh, and for carrying messages.

*Ducks* and *geese* have been bred from several wild ancestors (Fig. 294). The Canadian goose and the mallard duck have been tamed many times in North America. They are valued chiefly as holiday



FIG. 294.—The Canadian wild goose (brant). All geese, whether wild or domesticated, interbreed.

table birds. In this respect they are classed with the most recently domesticated of our common fowls, the *turkey*. This bird was domesticated by the pioneers in North America and has been crossed on a near relative from Mexico. It is still somewhat wild and inclined to wander away from home. The *guinea* and *ostrich* came from Africa, and the numerous kinds of *pheasants* from Asia.

**Review Questions.**—What was the ancestor of the dog? How do we know? Name some types of dogs. Compare them. What have dogs been used for? What do we learn from history about the domestication of the horse? What wild relatives of



the horse are known? Can hybrids be produced with them? Have these animals been of value in improving the horse? How? What can you tell of the wild asses? From what were Asiatic cattle developed? What was the ancestor of European cattle? How do these two kinds of domestic cattle compare? How was the cattalo produced? What can you tell about wild sheep? Why do domestic sheep sometimes have horns? Where did goats originate as domestic animals? Tell about the Angora goat. For what are goats used? What two wild hogs are ancestor to the domestic one? Compare the two types of domestic hogs. Make a list of the domestic birds and tell something about each.

#### STUDY 6. SCIENTIFIC ANIMAL BREEDING

**General Questions.**—Is crossbreeding popular with animal breeders? Is selection an important method? How do we improve poultry? How are cattle improved? What prospect is there for the domestication and improvement of certain wild animals? How is line breeding carried out? What is inbreeding? What is outbreeding? Under what conditions is grading advisable?

**How does man improve his domestic animals?**

**Crossbreeding** is not resorted to as much in animal breeding as in plant breeding. However, the mule is a hybrid, and is produced by breeding the female horse to the male ass. It is a valuable animal, but it does not produce offspring and probably never can be made to do so.

A notable instance of animal breeding by hybridization, where the relationship was not so distant as to make the offspring sterile, is the production of the Orpington breeds of poultry, which were produced by crossing several breeds. The Wyandottes (Fig. 295) were produced by the same method. Orpingtons were developed in England, and Wyandottes in the United States. The latter were produced by crossing and recrossing in an irregular manner the following breeds: dark Brahma, silver-spangled Hamburg, and the buff Cochin. Several breeds of dogs have been produced by crossbreeding also; but these are the chief examples of the use of this method by animal breeders.

**Selection** is the method of breeding on which the animal breeder must depend. Because of the great variety of breeds to choose from, very few new characters, or new combinations of old ones, are desired in domestic animals. What is wanted is intensification of certain characters,—such as egg-production in poultry, or quick-



FIG. 295. —Columbian Wyandotte, cockerel. Note the evidence of his Brahma ancestry in the color of the neck and tail. The chief distinguishing characteristic of Wyandottes is the shape of the comb. (*U. S. Dept. of Agriculture.*)

fattening in hogs. Such characters are often reduced rather than intensified by crossbreeding, and, hence, the modern animal breeder generally has little use for crossbreeds.

**Rhode Island Reds**, in contrast to Orpingtons and Wyandottes, were developed by selection. The history of this breed may serve as a good example of this method of animal breeding. It is reliably reported that in 1854 a sailor brought a large red rooster from Burma

to Adamsville, R. I. Because red chickens were a novelty, and because his offspring possessed vigor, the red rooster became the parent of a new breed of chickens. Many years of selection established the red color, and now the Rhode Island Reds are a well recognized breed.

**Greater egg production** is an object of selection in poultry raising which must be carried out very carefully if it is to be of value.

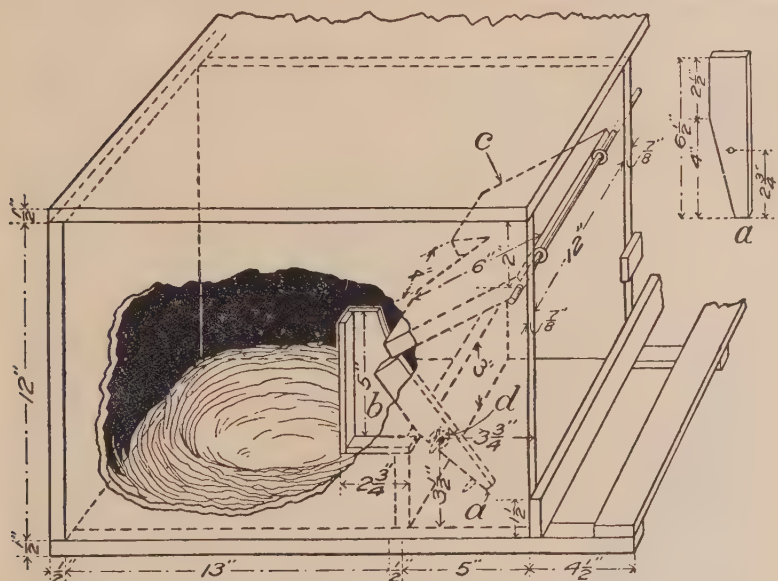


FIG. 296.—A good type of trap nest. When the hen enters the door (*c*) is lifted slightly. This permits the prop (*abd*) to fall inward so that when the hen passes the door it falls shut. (U. S. Dept. of Agriculture.)

It is impossible to estimate by looking at a hen how many eggs she will lay per year. The only sure way to find out is to keep a record of the eggs she lays from day to day. This is done by *trap-nesting* which consists in using nests of such a design that only one hen may enter the nest-box at a time, and she can not leave until she is released. Each hen wears a band on her leg which bears her number, and every egg she lays is credited to her. It has been shown by experiment that it is not necessary to take the record during the

summer in order to select the best layers. The winter record is sufficient to determine which hens are the most valuable.

By breeding from the best layers, and by using cocks which are bred from championship mothers, the average number of eggs laid by a flock can be raised from year to year. There are many flocks of poultry which do not average 100 eggs per year per hen. It is not profitable to keep such stock. In 1912-1913 the world's record for egg production passed the 300 mark with a record of 303 eggs in one year, made by a crossbreed between a Leghorn and a barred Plymouth Rock which was bred at the Oregon Agricultural College. This record shows that crossbreeds are not always poor in special characteristics.

If an egg record is to stand it must be made under official supervision in order to guard against error and deceit. Several claims to 300 eggs per year, or better, have been made in recent years. Perhaps the most startling record comes from England. It is reliably reported that Indian Runner Ducks have been selected to a standard of 300 eggs per year.

**Cattle.**—One of the most remarkable examples of animal breeding of modern times is the advances made in dairy cattle breeding. In such breeding the quantity and quality of milk produced and the value of the food consumed are carefully scored.

Cows have been bred which have produced more than 1,000 pounds of butter-fat per year. At 50¢ per pound the value of the butter would be \$500. Professor Fraser of the University of Illinois tested 554 cows from 36 commercial dairy herds and found that the best fourth of the total averaged 301 pounds of butter-fat per year, and the poorest fourth produced 133.5 pounds. He concluded from his experiment that 25 of the better class would yield as much net profit per year as 1,000 of the poorer ones. How many cows producing 200 pounds of butter-fat per year would it take to equal the record of a 1,000 pound cow? What light does the preceding record throw on the question, "Why do some farmers get rich, and others stay poor?"

It is not unusual for thousands of dollars to be paid for cows of exceptional individual records and which have good ancestry. Championship bulls have sold for more than \$50,000.

“Good judges believe that in the entire country one-fourth of the cows kept for their milk do not pay for their cost of keeping, and nearly a fourth more fail to yield annual profit. As a matter of ordinary business prudence and a condition essential to best results, every dairyman should study the individuality of his cows, keep a sufficient record of quantity and quality of milk produced, know approximately the cost of production, and systematically weed out his herd.” (*Bulletin No. 55, U. S. Dept. of Agriculture.*)



FIG. 297.—A muskrat. The raising of these animals in semidomestication has become a profitable business in recent years.

**The domestication of wild animals** is another important phase of animal breeding. The silver fox is a black variety of the red fox. The hair of the coat is black, tipped with white, giving a silvery effect which is very beautiful. These foxes are born of red parents occasionally and breed nearly true to type when bred together. Because of the great value of their pelts, the experiment of breeding



them in pens was tried, and was a success. Now hundreds of them are so bred, and by selective breeding their wild natures have been made more gentle, and the quality of their fur greatly improved. Breeding stock has sold as high as \$15,000 per pair, but it is much cheaper now.

The **raccoon**, **skunk**, and **muskrat** are bred in a semi-wild condition, but little effort has been made to improve the quality of their fur. The following will serve as an example of the possibilities of the business:

"The owner of a 1,300-acre tract of marsh, who traps with the aid of his two sons, in two seasons, 1909 and 1910, secured over 12,000 muskrats, which sold for more than \$9,000." (*Bulletin* No. 869, U. S. Dept. of Agriculture.) With the settling up of the country, and the consequent decrease of our wild animal life, the furs of commerce must come more and more from animals bred in domestication.

### SPECIAL METHODS OF ANIMAL BREEDING

Some of the methods used by animal breeders to improve the quality of their stock by controlling matings may be illustrated by describing the main types.

**Line breeding** consists in mating the grandparents to the offspring of the second, third, and succeeding generations. This is done to fix and perpetuate the characteristics of the grandparent. Certain animals are noted for their ability to stamp their offspring with their special characteristics. Such animals are said to be *prepotent*, and if the characteristics are highly desirable they are very valuable as breeders.

**Inbreeding** consists in mating closely related animals together. They may be brothers and sisters or cousins. This method has been objected to on the grounds that it tends to reduce the vigor of the strain. There is no reliable evidence to support this belief. Some of the best domestic stock has been developed by close inbreeding. However, if bad characteristics are present in the family, inbreeding and line breeding will increase them. Therefore, unless the stock is perfect these forms of breeding are not entirely safe. Among people, as well as among animals, there is no biological objection to the marriage of cousins if there are no physical or mental defects in the family.

**Outbreeding** consists in breeding animals that are not related or are distantly related, and has been much advocated by breeders in the past because of the belief just referred to that inbreeding causes the stock to run down. The scientific breeder of to-day does not consider that outbreeding is at all necessary. In fact, bringing in new blood may so break up the inheritance as to interfere with the increase of a character which is being worked for. It should be remem-

bered also that all stock will deteriorate more or less if it is not constantly selected for the maintenance of the standard type.

**Grading** is a form of breeding resorted to when it is desired to make over a herd or flock of scrub stock, and give it the characteristics of pure-bred stock. It consists in securing males of some pure-bred variety from which all offspring are raised. The first generation will be half-breeds, the second will be three-fourths pure, and so on. The scrub stock is gradually disposed of, and in a few years the herd will at least look like pure-bred stock. This method of improving stock is often necessary because of the high cost of the first-class material. Grading is always to be recommended when pure-bred material can not be bought outright.

**Review Questions.**—What are crossbreeds? How is the mule produced? How were Wyandottes developed? How were Orpingtons developed? How were Rhode Island Reds produced? For what may poultry be selected? Hogs? Cattle? How is trap-nesting carried out? What two kinds of fowls lay the most eggs? Why do many farmers fail to make a profit on their cows? How may the herd be improved? What wild animals show promise of profit under domestication? How is line breeding used to intensify a characteristic? Is inbreeding a bad practice? Is outbreeding necessary? Give reasons for the two previous answers. How is grading carried out?

## STUDY 7. VARIATION IN PLANTS AND ANIMALS

**General Questions.**—Are any two things ever alike in nature? What are continuous variations? What is Quetelet's law? What are discontinuous variations? Are malformations inherited? What is reversion? What is the cause of albinism? Are the black squirrel and the fox squirrel the same species? What is bud variation?

It is a matter of common observation that no two living things are ever exactly alike. In a grove of oak trees no two trees will be the same in the arrangement of their branches. The children in a family, even twins, are not alike. This difference in members of the same species is known as *variation* and is a universal biological fact.

Variations have been classified under two types. They are *continuous* and *discontinuous*, but some variations are difficult to place definitely under one or the other of the two classes.

CONTINUOUS VARIATIONS are small variations—such as the differences between leaves on a tree, difference in length of ears of corn, or a variation in redness of a ripe apple. These variations differ in number and extent according to the *law of probabilities* as announced by Quetelet, in 1846. The law is that there is a *mode* which is the average condition; and from this the variants differ both ways, *i.e.*, some will possess the character to a greater degree, and some to a smaller degree; and the greater number will resemble the modal type.

Davenport\* gives an example of the law of Quetelet for ear length of corn in which 286 ears were measured (Fig. 298). As shown in

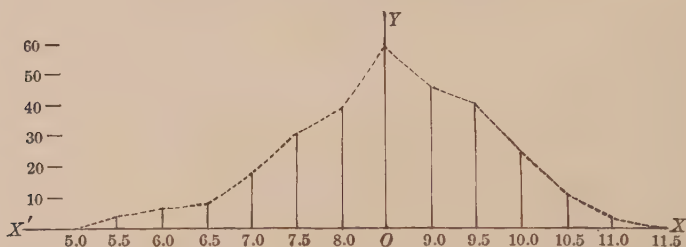


FIG. 298.—The frequency curve for the distribution of ear-length in the 286 ears of corn from Davenport. The length of the ears is written along the bottom line. The number of ears of each length is indicated by the upright lines and by the figures in the column to the left. The mode is a length of  $8\frac{1}{2}$  inches and is indicated by the line YO. (*Domestic Animals and Plants*, Ginn & Company.)

this table 59 were 8.5 inches long. Thirty-seven were a half inch shorter, and 46 were a half inch longer. Only one was as short as five inches, and only one as long as 11.5 inches. In this case 8.5 is the mode. When the data is assembled in a frequency curve we get a line which ascends to the mode, which is represented by 59 ears, and descends again on the other side.

DISCONTINUOUS VARIATIONS are large variations in which the character varying changes distinctly. They are not so common as the continuous variations and have been the cause of much dispute among biologists.

Darwin describes the famous ancon ram as follows: "In few instances new breeds have suddenly originated; thus in 1791 a ram-

\*Domesticated Animals and Plants.

lamb was born in Massachusetts, having short, crooked legs and a long back, like a turnspit dog. From this one lamb the *otter*, or *ancon*, a semi-monstrous breed, was raised; as these sheep could not leap over the fences it was thought that they would be valuable; but they have been supplanted by merinos, and thus exterminated." Another appearance of the ancon sheep took place in Norway in 1919.

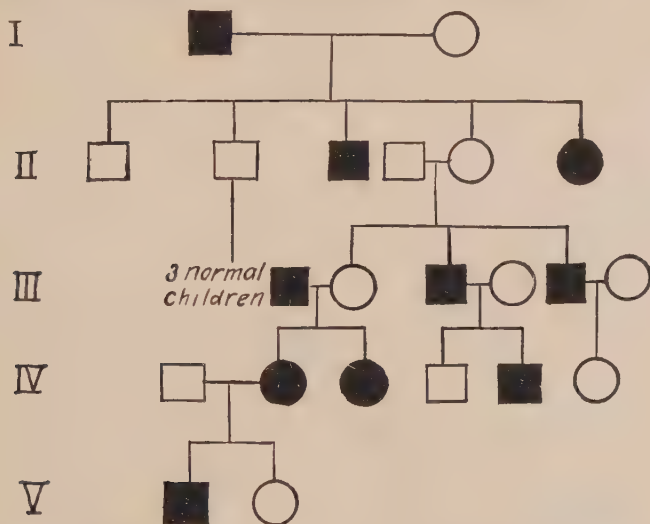


FIG. 299.—Chart showing the history of a case of polydactylylism (extra fingers). Note that the defect indicated by black figures runs through the five generations; originating in a man (square) whose wife (circle) was not affected. It appears twice in the second generation and is carried to the third generation by a normal woman. Both of her sons show the defect but her daughter does not. They all marry, the daughter marrying a man with the defect. Three cases occur in the fourth generation, and one in the fifth up to the time the record was made. (From "*Being Well Born*", by Michael F. Guyer. Copyright 1916. Used by special permission of the publishers, The Bobbs-Merrill Company.)

This was a female. Some of her offspring were like herself, showing the characteristic to be inherited.

Another case of a discontinuous variation is that of the hornless Hereford cattle of Kansas. In 1889 W. W. Guthrie of Atchison, Kansas, found a hornless bull calf in his herd. It was not a pure bred Hereford, but had some shorthorn blood in it. When it matured

and was used in breeding, its calves were, to a remarkable extent, hornless; and a strain of hornless Herefords was developed.

De Vries gives a long list of discontinuous variations in his book on mutations. These variations have been called *rogues*, *saltations*, *sports*, and *mutations* by various authors. It very seldom, if ever, happens that an entirely new character arises by discontinuous variation. In most cases some character is reduced, but a character may be enlarged. These variations are apparently more apt to occur when there has been some crossbreeding in a previous generation and are thought to be Mendelian variations, which will be discussed in the next study.

We shall now discuss four of the many forms of discontinuous variations which we will term *malformations*, *reversion*, *albinism*, and *bud variation*.

**Malformations**, such as six fingers on one hand, extra horns on sheep, harelip and cleft palate in man are distinct variations and may be caused by (1) something which interferes with the development of the embryo in which case they are not inherited, or (2) they may be inherited, and, hence, are due to something which was present before the embryo began its development. Extra fingers or lack of them in man are definitely inherited conditions and reappear again and again in families where they have once appeared (Fig. 299).

**Reversion** is a "throw back" to an ancestral condition. Devon cattle have descended from the wild park cattle of England and Scotland which were mentioned in Study 5 of this unit. Although Devon cattle are a solid red in color, they sometimes give birth to offspring which have the characteristic markings of the wild park cattle. Another example may be found among pigeons. If various kinds are permitted to breed without selection, the characteristic markings of their wild ancestor appear in the bars on the wing in a few generations. Reversion is a commonly observed variation in many plants and animals. Discuss other examples in class. Crossbreeding seems to increase the number of young which show this variation.

**Albinism** is the occurrence of white individuals. It may occur in almost any kind of animal. White specimens of crows, sparrows, deer, and all varieties of domestic animals are known. The condi-



tion is due to a lack of pigment in the feathers or hair, and is strongly inherited if albinos are mated together. *Melanism* is the occurrence of black color in a similar manner. (See Fig. 300.)

**Bud variation** is a type of variation in which a bud sends forth a shoot which is different from the other shoots of the plant.

Sugar cane produces no seed and is always reproduced from cuttings. One of these cuttings produced a peculiar striped form which is hardy and rich in sugar. It is grown extensively and is known as *ribbon cane*. The *nectarine* arose from the peach, more than once, as a bud variation. It is also reported that peaches have arisen from nectarines by the same process.



FIG. 300.—A black squirrel and a fox squirrel. The black squirrel is a melanistic variety of the fox squirrel, or of the gray squirrel. This one is a fox squirrel.

### SUGGESTED LABORATORY WORK

Make a study in the laboratory to illustrate the law of chance which is called the law of Quetelet in biology. It may be done with ears of corn, by counting the number of rings in the bodies of fifty earthworms, by measuring the size of leaves, the height of weeds, the length of peach stones, and in many other ways.

It may be done in a mathematical way with inanimate objects, such as checkers, pennies, buttons, etc. Throw them up and note which side is up. Keep a record of a large number of trials. Calculate what your results should be and compare with what you get. Plot the curve.

Invite a public spirited insurance agent to make a talk to the class on the operation of the law of chance in regard to human life.

**Review Questions.**—Give some common examples of continuous variations. What is the law of probabilities, or Quetelet's law? How does it work out with ears of corn? Tell about the ancon breed of sheep. Tell about the hornless Herefords. What are some of the other names which are given to discontinuous variations? Give some examples of malformations. Describe reversion in Devon cattle. How does it work out in pigeons? What animals do you know to produce albinos? What ones may produce black individuals? How was ribbon cane produced? How did nectarines originate?

#### STUDY 8. MENDEL'S LAWS OF HEREDITY

**General Questions.**—What is heredity? Can blue Andalusian fowls be made to breed true to type? Why do blue Andalusians produce black and white offspring? What is the law of segregation? In breeding Andalusians what ratio of blacks, whites, and blues appears in the succeeding generations? What would be the color of the offspring if a black and a white guinea pig should be mated? What are dominant and recessive types? Tell the story of how Gregor Mendel discovered his laws of heredity.

The fact that offspring—both of plants and animals—resemble their parents is known as *heredity*. In 1899 a prominent zoologist wrote, "It is easier to weigh an invisible planet than to measure the force of heredity in a single grain of corn", but so rapid and remarkable has been the advancement of learning concerning heredity that many of its most important mysteries have been reduced to scientific laws.

**Andalusian Fowls.**—We shall begin our study of heredity by examining the case of the Andalusian fowls. They are much like leghorns and are of three colors—one being black, another white "splashed" with a few black feathers, and another blue. The blue ones are not really blue but are grey, a mixture of black and white (Fig. 301).

For a long time poultry raisers tried to breed the blue ones true to type, but they continued to produce some offspring of the black and white types. It was at first thought that if they were selected long enough this tendency would disappear, but it did not. After years

of selective breeding the blues continued to produce just as many blacks and whites as at first, and no more and no less. The whites always produced whites and nothing else, and the blacks always produced blacks. It was found by experiment that when white ones were bred to black ones the crosses or hybrids were always blue without a single exception. Therefore, it was concluded that the blue ones were a hybrid type and could not be made to breed true; *but why should they produce blacks and whites which were absolutely*

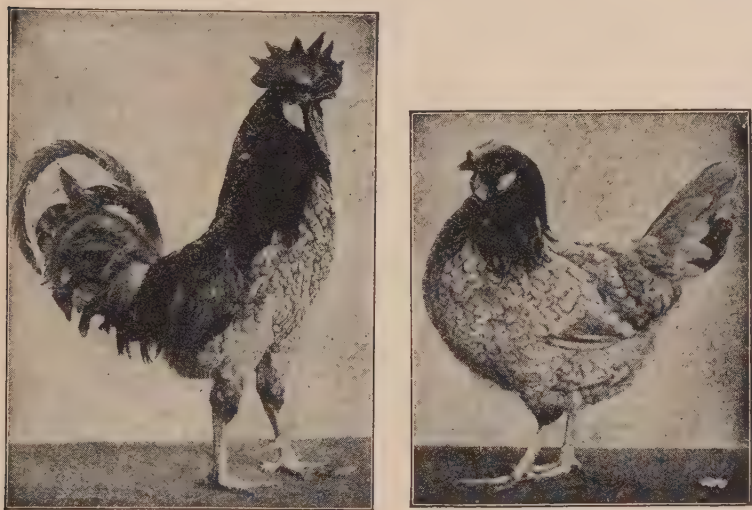


FIG. 301.—A blue Andalusian cock and hen. (Jewett, *The Next Generation*, Ginn & Company.)

*true to type when bred?* This fact, that the blacks and whites which were produced by the blue hybrids were as pure blooded as the original blacks and whites, was very puzzling.

**The Law of Segregation.**—The mystery of the blue Andalusian fowl is explained by the law of segregation which is that certain characters like black and white, in this case, do not actually blend in breeding, but only appear to in the first generation. These characters retain their identity and come out in some members of the succeeding generations as pure characters, unaffected by the

crossbreeding which has taken place. Like oil and water, they will not mix permanently. (See Fig. 302.)

**The  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{1}{4}$  Ratio.**—The number of black and white Andalusian fowls which occur when the eggs of blue ones are hatched is a definite ratio to the number of blue ones which are produced. The chart shows this ratio which, of course, holds true only when large numbers are considered. It might not be true if only ten or twelve chicks were compared.

Study the chart carefully and see that the original parents are black and white. The first generation of offspring are blue. The

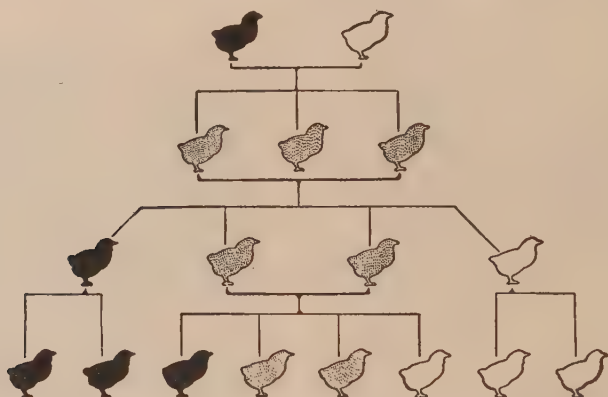


FIG. 302.—Chart showing color inheritance in Andalusian fowls. (Jewett's "The Next Generation", Ginn & Company.)

second generation of offspring are  $\frac{1}{4}$  black,  $\frac{1}{2}$  blue, and  $\frac{1}{4}$  white. In the second generation if the blacks are bred to blacks all of the offspring are black; if the whites are bred to whites all of the offspring are white; and if the blues are bred to blues, the  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{1}{4}$  ratio is again repeated. This ratio will continue to appear as long as blues are bred together.

**The Law of Dominance.**—If a black and a white guinea pig are mated all of the offspring in the first generation will be black (Fig. 303) instead of blue as in Andalusian fowls. In this case black is said to be *dominant* to white because it "dominates" over it—*i.e.*, obscures it completely instead of only partly. In the succeeding

generations, if the black-white hybrids are interbred the ratio is  $\frac{3}{4}$  black to  $\frac{1}{4}$  white; but  $\frac{1}{3}$  of the black ones are pure black and will breed true, while  $\frac{2}{3}$  of them are hybrids. Thus we see by examining the chart that the only difference between guinea pigs and Andalusian fowls is that in the case of the guinea pigs the hybrids are black instead of blue, and it can not be determined which are pure black and which are hybrids until the fact is revealed in breeding in the second generation of offspring where the pure blacks breed true, and the hybrids repeat the  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{1}{4}$  ratio.

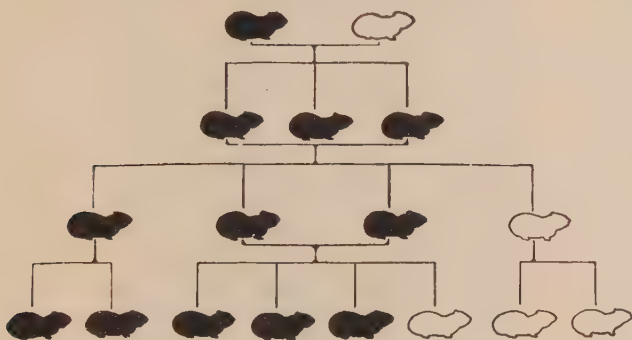


FIG. 303.—Chart showing color inheritance in guinea pigs. (Jewett's "The Next Generation", Ginn & Company.)

*The law of dominance is that when two characters stand in opposition to each other one may completely replace the other in appearance in the first generation of offspring.*

There are many cases which show partial dominance to a greater or less degree, as in smoothness and bearding in wheat. Smoothness is regarded as the dominant character, but often there is a tendency to form a beard in the first generation. Thus there are cases of *complete dominance* as in black and white guinea pigs, cases of *partial dominance* as in smooth and bearded wheat, and cases of *no dominance* at all as in the blue Andalusian fowl. (Fig. 272.)

Characters which are obscured by dominant ones in the first generation are said to be *recessive characters*—i.e., they "recede" in the presence of dominant ones. White is recessive to black in guinea pigs.



**Gregor Mendel's Discovery.**—Gregor Mendel was an abbot at Brünn, Czecho-Slovakia. He experimented with peas in his garden and discovered the three laws which have been discussed in this study. The law of segregation, the law of dominance, and the appearance of the  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{1}{4}$  ratio are known as Mendel's laws.

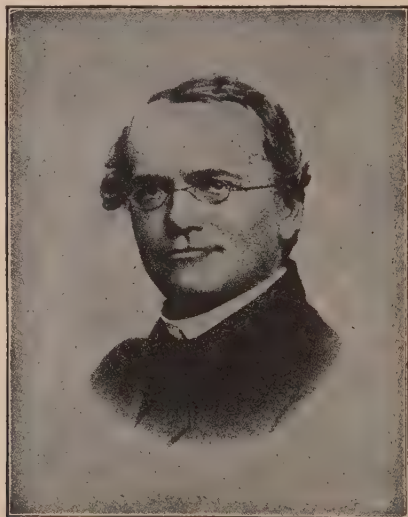


FIG. 304.—Gregor Mendel at the age of forty. (*Gager.*)

Mendel worked on peas for eight years before announcing his conclusions, and worked with the following characters which are arranged below according to dominance.

| DOMINANT                                        | RECESSIVE               |
|-------------------------------------------------|-------------------------|
| 1. Green pod (unripe)                           | Yellow pod              |
| 2. Inflated pod                                 | Constricted pod         |
| 3. Tallness                                     | Dwarfed                 |
| 4. Flowers arranged along the axis of the plant | Flowers bunched at top. |
| 5. Seed skin colored                            | Seed skin white         |
| 6. Cotyledons yellow                            | Cotyledons green        |
| 7. Seed smooth                                  | Seed wrinkled           |

Mendel's papers were published in 1865 and in 1869. "When he read his papers to the scientific society at Brunn, he himself was excited and enthusiastic, but he saw plainly enough that those who listened were neither excited nor enthusiastic. Indeed, they hardly seemed even interested, and when the reading was over, Mendel's own excitement was gone. His heart was heavy with disappointment. He had expected so much, yet nothing came of it. After that his papers were simply printed and packed away to gather dust in the Brunn library. And here they stayed, out of sight and out of mind, for thirty-four years. Fortunately, however, during all these years the library had them in safe keeping."\*

Mendel's forgotten papers were found about 1900 when de Vries in Holland, Correns in Germany, and Tschermak in Austria rediscovered Mendel's laws, each working independently. Even then the papers might have escaped the knowledge of the world, but for the fact that there was some controversy as to who the real discoverer of the laws was. The publicity attending the dispute aided in bringing forth the documents and establishing Mendel as the discoverer, much to the surprise of all those concerned. (Fig. 336.)

**Review Questions.**—State how Andalusian fowls illustrate the law of segregation. Do they illustrate the law of dominance? How do guinea pigs illustrate dominance? How do both of these illustrate the law of ratios? What are recessive characters? Describe Mendel's experiments. How did it happen that he was finally given credit for his discovery?

#### STUDY 9. EUGENICS, THE IMPROVEMENT OF MANKIND

**General Questions.**—Do the laws of heredity affect mankind as they do plants and animals? How do acquired defects differ from inherited ones? Are our best educated families maintaining their numbers? What are some of the defects of mankind which may be inherited? Have we room in our public institutions for our defectives? Are they increasing in numbers? What can be done to reduce the number of defectives?

The fact that man is subject to the same laws of variation and heredity which obtain in the plant and animal world has been known

\* F. G. Jewett, *The Next Generation*.

for a long time. The great Greek philosopher, Plato, protested against allowing defective individuals to produce offspring and thus lower the standard of the race.

All defects, either mental or physical, to which man is subject may be classified as either *acquired* or *inherited* as to their cause. If they are acquired they will affect only the one person who has them, and will not be passed on to future generations. If they are inherited they will be passed on from generation to generation.

**Physical deformities**, such as humpback, harelip, deformed hands and feet, cleft palate, and tongue-tie are inherited and are known to prevail in certain families. Deafness and blindness may be either inherited or acquired.

**Bacterial diseases**, such as tuberculosis, syphilis, and pneumonia are not inherited; but *a poor resistance to the disease is inherited*, and if the disease occurs in a family the well members are especially apt to take it because of the increased opportunity for infection to take place.

**Insanity, paralysis, and feeble-mindedness** are the worst forms of inherited defects because they are difficult to detect in many cases until after the period of childhood has passed. All forms of insanity are not inherited, but most varieties are. Feeble-mindedness is a recessive, Mendelian character and follows the Mendelian ratio in inheritance. If both parents are feeble-minded all of their children will be feeble-minded. *Epilepsy* is known to run in certain families and is due to an inherited, defective nervous system.

There are only two fortunate circumstances in this matter. They are that (1) defective strains have a relatively high death rate, and, hence, there is a tendency for their numbers to be reduced; and (2) that it is possible by fortunate matings to completely breed out some defects in a part of the offspring. However, both of these tendencies are more than offset by the fact that the birth rate among defective people is extremely high, that the death rate of some classes of defectives is low. Defectives are multiplying faster than the normal people.

**Race Suicide.**—It is a lamentable fact that families which are the best mentally do not average three to four children per family which is the estimated number necessary to maintain the race. Statistics

have been gathered to show that university graduates do not adequately maintain their numbers, and the college graduate type must be constantly recruited from the children of parents who are not graduates. The failure of a race to produce enough children to successfully maintain itself is known as *race suicide*. This unfortunate situation was very disturbing to the late Theodore Roosevelt, and he wrote and spoke against it on many occasions. He is largely responsible for the use of the phrase "race suicide". From a biological point of view, there is no greater tragedy than the suicide of a worthy class of people.

**The Feeble-minded.**—It is estimated that not over one-tenth of the feeble-minded are in institutions. Nine-tenths of them are free to reproduce their kind. For the past hundred years we have been building more, and more, and more institutions for the care of these unfortunate people, and the facilities are still entirely inadequate. Nearly every state institution in the country is full to overflowing, yet the remedy for all this is very simple. *If we can prevent them from breeding, in a few generations there will be few of them.* This is certainly an altruistic and merciful thing to do.

**The Jukes family** is a typical case of what may happen if we neglect our duty and let the defectives live free lives and reproduce their kind among us. There are 1,200 known members of this family, and many more are being produced. It includes 310 professional paupers, 300 deaths in infancy, 440 physical wrecks from debauchery, 50 immoral women, 60 habitual thieves, 7 murderers, and 130 other criminals. At the time the record was made this family had cost the State of New York \$1,250,000.

All this would not have been if the original ancestor had been prevented from producing offspring. We have reduced the breeding of plants and animals to a very efficient science, but have done practically nothing until recently to improve the human race from the standpoint of eugenics.

The methods of saving us from an over-production of defectives group themselves under four heads.

1. Our immigration laws must be enforced so as not to admit any defectives or relatives of defectives. This situation is now satisfactory.

2. The present method of isolating only 10% of our defectives must be improved so that at least 90% of them are isolated and prevented from producing another generation like themselves
3. Those which cannot be kept in institutions must be sterilized.
4. Education, both of those affected and of the public, concerning the principles of eugenics, should be everywhere encouraged.

**“Eugenics** is the study of the agencies under social control, that may improve or impair the racial qualities of future generations, either physically or mentally”. (Galton.) It has two fundamental purposes. One is to reduce the number of the unfit by preventing them from being born. The other is to encourage a greater production of the fit in so far as this is possible.

It is not expected that very much will be done to improve the human race directly. Normal people must be allowed to marry as they choose, but a knowledge that defects are inherited may prevent those who have foresight from marrying into families where these defects are prevalent. Some of our states have laws which forbid people who have inherited defects from marrying. The chief aim of eugenics at the present time is to reduce the number of defectives.

**Review Questions.**—Name some inherited defects. Why do bacterial diseases sometimes run in families? Where is the death rate the highest, among defective or normal people? What is meant by “race suicide?” How well do we care for our feeble-minded? What does the record of the Jukes family show? What may be done to reduce the number of unfit? Define eugenics. What do scientists expect to accomplish by making use of such information as is set forth in this study?

#### STUDY 10. EUTHENICS, THE IMPROVEMENT OF LIVING CONDITIONS

**General Questions.**—In asking these questions it is not intended that there shall be a recitation on this study. It should be read and thought about. When the class meets the problems which are raised should be discussed. There will be no review questions at the close of the study. How may the life of the home be improved? How may the life of the school be improved? How may the living conditions in the community be improved?



**What community efforts are necessary to eliminate contagious diseases?**

If we, the people of North America, are to continue as leaders in the progress of the world it is not enough that we strive to improve our people by eugenics alone. Inheritance counts for much, and a good inheritance is essential to a successful life; but good inheritance avails little if the environment is not also good.

The effort to elevate the race by improving the environment is known as *euthenics*, and is fully as important in our civic life as eugenics. Space does not permit us to more than call attention to some of the significant phases of the problem.

**How may the race be improved by improving its environment?**

**The Home.**—Euthenics begins with the home. The home-life of our boys and girls must be of the best. The child who is raised in the crowded parts of our large cities is greatly handicapped. The city which permits filth and dirt to accumulate around poorly built tenement houses is sowing seeds for a harvest of boys and girls which will cost it dearly in its hospitals and police courts. No city should permit poorly lighted, heated, and ventilated tenement houses to be built.

It is especially necessary that all bedrooms be properly ventilated. About one-third of a person's life is spent in sleep during which time the purest air obtainable should be had.

Every boy and girl should take pride in the home. It should be seen to that the lawns and flower-beds are kept in good order. Trees should be planted for both shade and beauty, and they should be properly cared for. They should be well trimmed, and kept free from insect pests and disease. No city can be beautiful without beautiful lawns and trees. The trees are often cared for by the city department of forestry. Has your city such a department? Has your city a law compelling property owners to plant trees along the street? Make a census of the city and report the number and condition of the trees.

**The School.**—Have you a school physician and a school nurse? What are adenoids? Have a report given on them. All school children should be inspected at least once a year for adenoids, poor teeth, defective eye-sight, defective hearing, and general health.

These defects must be remedied while the child is young if they are to be remedied at all. Has your class been inspected this year? If not, can you interest your superintendent and school board in regard to this important duty? Neglect is more costly in both money and poor health than present expenditure can possibly be. We are the richest nation in the world. Surely we can afford the money necessary to save the health of our children. In most schools

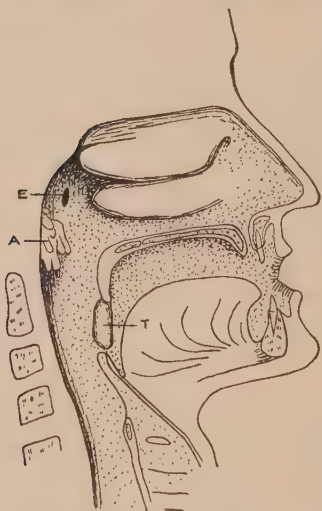


FIG. 305.—Diagram of the throat and nasal passages to show the location of adenoids and tonsils. A, adenoids; E, opening of Eustachian tube to ear; T, tonsil.

25% of the children are suffering from adenoids, poor sight, defective hearing, or decayed teeth; and in some schools the number is as high as 50%. Many students who are considered backward are able to do good work when these defects are remedied.

Is the *lighting, heating, and ventilation* in your school perfect? Discuss these three problems in class. They are very important.

*Athletics* should be encouraged for every boy and girl in school. In the past practically all of the attention was given to the few who were able to "make the team", while those who needed the benefits of athletics the most received none, or very little. The athletic training should be of a kind that will build up strong and

healthy bodies for all students.

*Child labor* is rapidly becoming a thing of the past in the United States, because it is a poor national policy to neglect the development of the minds and bodies of the growing generation. Compulsory education in some form should continue until the age of eighteen is reached.

**The Community.**—It is the duty of every city to supply its children with well equipped playgrounds. The need is not so great in small towns where there is room for the children to play, but it is an abso-

lute necessity in large cities. Has your city a skating pond large enough to accommodate all of its children? Has it an improved, free bathing beach? A stream or pond may be available, and should be supervised, no matter how small the town may be. What can you do to help get a skating pond and a bathing place for the improvement of the health and life of the young people of your community?

The United States government has good laws protecting its citizens against adulterated (impure) foods, but these laws can not be effective unless the citizens of the community are willing to aid in their enforcement. Are they enforced in your community?

Are the herds from which your milk comes inspected for tuberculosis, and are the stalls kept clean? Do you know where your milk comes from? Give a report in class on the dangers of impure milk. In addition to the large sums spent by the states, the United States Government spends upward of \$4,000,000 annually to fight cattle tuberculosis. As a nation we are making great progress in the fight against this disease, but some communities are backward, and their people are still dying of tuberculosis.

Are there any flies in your grocery store and meat market? What are some of the things that boys and girls can do to keep the places where food is sold free from dirt and germs? Borrow from the International Harvester Co. of Chicago, Ill. their free set of lantern slides (or charts) on the house-fly.

**Contagious Diseases.**—The late President Roosevelt said in a message to congress, "There are about 3,000,000 people seriously ill in the United States, of whom 500,000 are consumptives. More than half of this illness is preventable. If we count the value of each life lost at only \$1,700 and reckon the average earning lost by illness at \$700 a year for grown men, we find that the economic gain from mitigation of preventable disease in the United States would exceed \$1,500,000,000 a year."

Who are the members of the board of public health of your city? Who is the health officer? You should know who they are. Are the quarantine laws rigidly enforced? Discuss in class why you should be concerned about this matter. It is a disgrace to any city now to have an outbreak of typhoid fever, smallpox, or yellow fever. They are all caused by germs and can be prevented.

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## UNIT X. THE CONSERVATION OF BIOLOGIC WEALTH

"Each generation has a right to all it needs, but no right whatever to waste what it does not need". (Gifford Pinchot.) America has always been the land of plenty. We have given little consideration to conservation. The forests were thought of as being in the way of developing agriculture. Many wild animals were pests. For instance, the passenger pigeon descended upon grain fields and consumed the ripened grain. No one cared to protect it. Now it is extinct. Land was plentiful and could be had by occupying it. Soil conservation was not necessary, nor was it economically profitable.

Now a great awakening has come. We are aware that much of our soil is depleted as is testified to by the thousands of abandoned farms in the older parts of the country. In many states the forests are practically gone. Our wild game is preserved in small numbers by game laws and is exterminated over wide areas, where it will never return. Our streams and lakes are fished out to the extent that only rarely is a good day's fishing to be had.

It is our duty to understand this problem in a scientific way, and not in a sentimental or emotional mood. There is much said and written about conservation which is of no value or is impossible of accomplishment. For instance, it is not good economics to try to raise a forest on land which is well suited for growing grain. The grain crop is the more valuable. On the other hand, there is much land which is well suited for growing trees which is allowed to go to waste, and no benefit is being derived from it.



## PROBLEM I. HOW MAY OUR FORESTS BE CONSERVED?

**General Questions.**—What is the business of forestry? What trees may be planted in forest projects? What is the chief interest of forestry? What are some of the secondary advantages of forestry? How do forests maintain themselves? How may the government aid in forestry projects? What may be done to improve our forest trees? What are the dangers which threaten our forests? How are forests related to wild life?

The business of forestry is in its infancy, and the profits to be expected are uncertain. Furthermore, the investor in forest projects must wait several years to realize a profit. It is not advisable to plant trees for lumber on good agricultural land, but on land that is now idle trees may be planted, or encouraged to grow, and some day a handsome return may be realized. Then, if the trees are cut properly and cared for, the supply of lumber will be continuous and permanent.

*Forestry is the business and science of profitably maintaining tree life.* The chief forest industry is lumbering. It has been said that lumber is man's most useful material. We make many things of lumber, and put it to many uses. The range of usefulness is very great as we may see if we recall that matches, toothpicks, railroad ties, furniture, machinery parts, boxing, fuel, paper, fences, scaffolding, and buildings are all made of the wood of trees. During the past half century there has been a great increase in the use of metals and various compositions as substitutes for, or improvements over, the use of lumber. All of these developments are welcome and are to be encouraged, for if other materials were not used, our lumber supply would be nearly exhausted at the present time, and the price of lumber would be very high.

**Other Interests.**—While lumbering is the chief interest of forestry, it is by no means the only one. Some land soon becomes worthless when the forests are removed. Water is retained by the leaf mold

on the floor of the forest, and the shade prevents its evaporation. As long as the trees remain, the land is productive and the soil remains fertile. When this protection is gone, the soil may be washed away and the bed rock, or infertile subsoil, exposed. This is not apt to occur on rich, level land but if the subsoil is loose sand, as is the case along much of the eastern shore of Lake Michigan, sand dunes develop and the land becomes worthless; or, if it is hilly, gulleys may develop.

When the forests are gone the rain water which they formerly retained rushes down the hill sides carrying with it the fertile soil. It carves out gulleys, floods streams, overflows lowlands, and fills navigable rivers with silt. All land that will support tree life and that is not suitable for agriculture should be planted with trees.

Values are not all measured in gold. Trees are valuable for their beauty and shade. The woods, groves, and solitary trees of a landscape add a necessary, artistic value that can not be reduced to mathematics. What would our city parks and streets be without their trees and the birds that live in them?

Aside from furnishing lumber, shade, and beauty trees have many other economic values. If time permits some of the following topics may be assigned and reported on in class: relation of trees to avalanches and land slides, wind breaks, wild fruits and nuts, maple sirup, rosin, turpentine, camphor, quinine, rubber, creosote, cinnamon, cork.

**Classification.**—Forest trees may be classed as *evergreen*,—those that usually have needle-like leaves, bear cones, and remain green throughout the winter; and *deciduous*,—those that have broad leaves which are shed in the fall. More than three-quarters of our timber supply is furnished by the evergreen trees. They are all classed as *soft woods* although some of them are quite hard and strong. The broad leaved trees are either hard or soft according to the weight and strength of their wood. Oak, maple, hickory, and walnut are classed as hard woods and are now very high priced. Basswood, sycamore, tulip tree, and poplar are soft wood trees. Woods,—like birch, elm, ash, and gum are intermediate in grade and are being drawn upon to take the place of the rapidly disappearing hard woods.

The kind of trees to plant in a forest project depends upon the climate, the condition of the land, and the use to be made of the

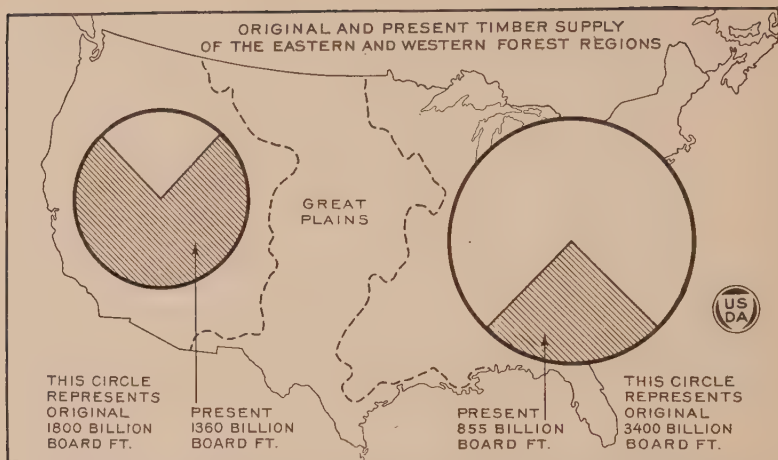


FIG. 306.—Our timber supply, in reality probably far greater originally than the 5,200 billion feet shown in this figure, is now reduced to about 2,200 billion feet. (Courtesy U. S. Forest Service.)

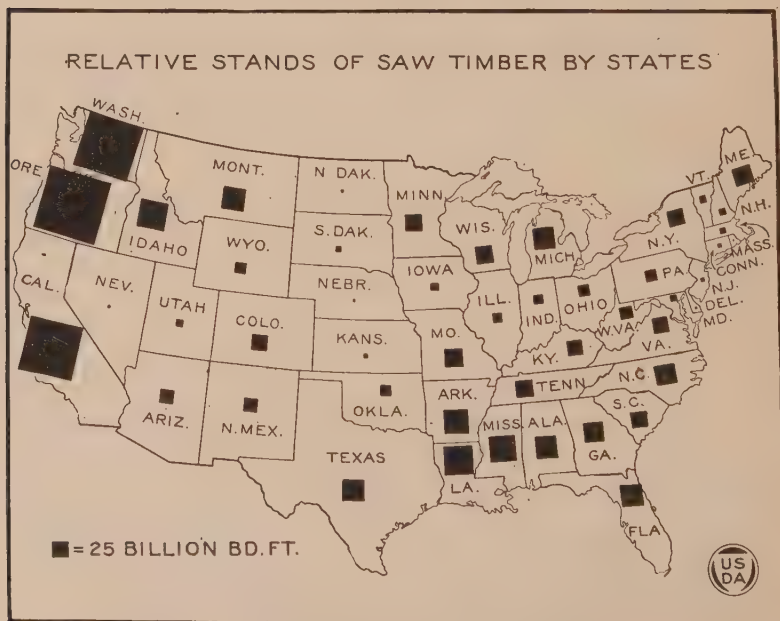


FIG. 307.—Most of our standing timber is in the South and West. The Middle Western and Northeastern States, though our largest consumers of timber, are far from producing the timber they use. (Courtesy U. S. Forest Service.)

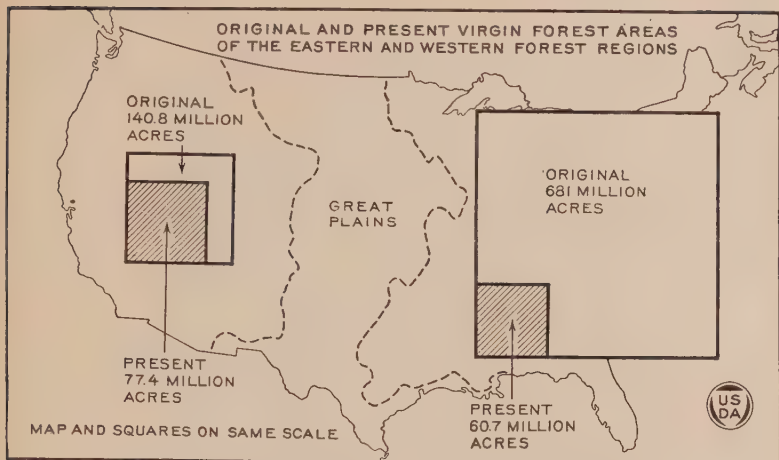


FIG. 308.—But a small portion of the eastern forest lands remain, and nearly half of the western areas have been cut. (Courtesy U. S. Forest Service.)

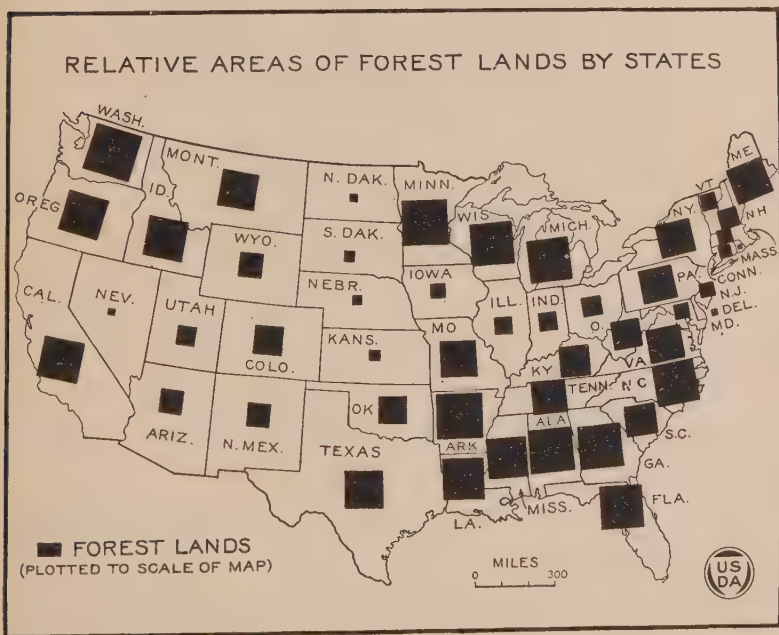


FIG. 309.—Though the original forests have largely disappeared, we still have plenty of forest land, if rightly used, to grow the timber we need; and the most of this land is in the East, where timber is most needed. (Courtesy U. S. Forest Service.)

product. Spruce and white pine have been planted in the East. In the South the various forms of eucalyptus from Australia, especially *Eucalyptus globulus*, give great promise because of their rapid growth. Hard woods grow very slowly, and because of this, it may be wise to plant the soft woods which grow more rapidly. The age of a white oak tree is beyond that of the average length of the life of man before it is ready to be cut for lumber. Other hard woods grow nearly as slowly.



FIG. 310.—Winged fruits of the basswood. The fruits are borne in clusters and are attached to a bract which enables the wind to carry them away. They often hang on the tree until after Christmas, and are seldom detached except when a strong wind is blowing.

**Forest Reproduction.**—Under natural conditions trees maintain themselves. Their most common method of reproduction and distribution is by seeds. The seeds of pines, maples, ashes, and elms have “wings” and sail in the wind (Fig. 310). Those of cherries, oaks and hickories are carried by birds and squirrels. Cottonwoods and willows send up sprouts from their roots. The chestnut, ash, and oak send up sprouts from their cut stumps. Woodlands are



more rapidly renewed by sprouting than by growing from seed. Such growths are called *coppice* woodlands (Fig. 311). In many



FIG. 311.—Coppice sprouts of the basswood growing around a small stump.  
Can they all survive and produce trees?

localities nature does not replenish the tree growth and artificial seeding or transplanting must be resorted to.

**Forest Conservation Program.**—If we are to accomplish anything in our campaign of saving our forests and conserving them as per-

manent sources of lumber for future generations, we must have a national policy. Such a policy is outlined by H. S. Graves, U. S. Forester.

1. *Fire Protection*.—The public should directly share the burden of fire protection, especially in a preventive system and in the cost of suppression.

2. *Assistance in Forestry*.—The public should assist owners in working out plans for cutting that will promote natural reproduction, in planting, and in other measures of forestry. The State should offer planting stock at cost and coöperate with the owners in establishing plantations.

3. *Taxation*.—The States should adopt a form of taxation calculated to encourage good forest practice. The present methods of taxation, with their lack of uniformity in application, often tend to promote premature and wasteful cutting and to discourage forest renewal. To promote action by the States, the Federal Government should help the States to investigate the current methods of taxation and their effect in causing premature and wasteful cutting and in increasing the difficulties of holding cut-over lands for tree growth, and should assist in drafting model tax laws applicable to various forest conditions.

4. *Forest Loans*.—It has been suggested that existing legislation concerning farm loans should be extended to include loans for the purchase and improvement of forest lands, to encourage the holding of lands previously acquired, where the purpose of the owner is to hold and protect cut-over lands or those having growing timber, to reforest lands by seeding or planting, or to use other measures in promoting forest production. To obtain the benefit of such loans, which should be for a maximum period of 50 years, the land owner should enter into a specific obligation to retain the land in growing timber and protect and care for it during the life of the loan.

5. *A Survey of Forest Resources*.—Funds should be provided whereby the Federal Government in coöperation with State and private interests may make a survey of the forest resources of the country. This would determine the quantities of timber suitable for different industrial uses, the current consumption of forest products, the probable requirements of the different regions for material, the possible production of the forests by growth to meet these requirements, and other matters which will aid in developing and carrying out the national forest policy.

6. *Land Classification*.—The public should coöperate in land classification to aid owners to put their lands to the most productive use. The public should aid in bringing settlers upon lands suited to agriculture, and at the same time should discourage speculative undertakings that lead to the deception of innocent investors and efforts to colonize lands which are not suited to settlement.

7. *Research Work*.—Adequate funds should be provided to enable the Government and other public agencies to carry on investigative work needed in carrying out a national policy of forestry. This would include investigations on a larger

scale than at present for determining the best methods of forest practice, and also research in forest products.

8. *Forest Insurance*.—As soon as forest property becomes secure under systematic protection, fire insurance comes within the range of feasibility. Every encouragement should be given to plans of insurance such as that already inaugurated in the Northeast.

**Conservative Lumbering.**—In the past, trees have been so plentiful that little attention has been paid to conservative methods of lumbering. Trees should be cut close to the ground so as to avoid waste in the stump. The tops should be made into fence posts and firewood. Trees should stand close together to make tall, clean trunks, but if they are too thick they will not grow rapidly, in which case the small ones may be removed and used as fence posts. When a tree is felled it should not be allowed to break down younger and promising trees. Much valuable timber has been destroyed by forest fires which are usually preventable. When fire passes through a forest everything is destroyed. Even the soil is burned out leaving the hillsides to be gullied by the rain water.

The need of preserving our forests is great. In former years the forests were in the way of agriculture. The pioneers destroyed the trees to make room for crops but now the forests are so reduced in the settled parts of the country that an effort is being made to reestablish, on land not suited to agriculture, the forest that has disappeared. The Federal Government has set aside over 167,000,000 acres of forest land in the western states, and the State of New York has established the Adirondack Park of 1,500,000 acres in the interest of forest conservation. These are but two of the examples which might be given of our strenuous efforts to repair the waste which has taken place, and to prevent such further losses as we may.

**Tree improvement** may be a profitable business for the experimental breeder. The Norway spruce and the soft maple have been improved as shade trees, but little has been done to improve our trees used for lumber. Burbank has produced a hybrid between the English and American black walnuts which shows great promise in the rapidity of its growth and the quality of its wood.

**Forest Enemies.**—1. The greatest enemy of our forests has been the *lumberman* who has been interested in an immediate profit

with little concern for the future. This menace promises to become less dangerous from now on.

2. *Forest fires* have burned much of our valuable timber. They are especially prevalent in cut-over land. Scientific study shows that they are caused by campers and smokers, railroads, are wantonly set, and by burning brush in the great majority of known cases. These four causes are responsible for 70% of our forest fires. The damage done by fires not only destroys grown trees and burns out



FIG. 312.—An example of destructive forestry in Colorado. Note the waste caused by cutting the stumps high. The area was cut clean for charcoal. No young trees were left. The soil is being washed away in the right foreground. (Photo by S. T. Dana, Courtesy U. S. Forest Service.)

new growth, but it is the chief danger which is feared by those who might start forest projects. They fear that their investment will be destroyed by fire before the tree crop can be harvested.

3. *Agriculture* is a rival business to forestry. It is ever demanding more land and abandoning the land which no longer proves to be profitable. The soil where a forest has been cut is usually fertile, but it does not always remain so. It frequently happens that the forest is cut, the land is converted to agriculture, and the crops are

good for a few years. Then the soil is depleted, and the land is abandoned to weeds and brush. These stretches of country are burned out by fires every few years, so that the trees never return to the land where they once grew.



FIG. 313.—A good stand of spruce and balsam. This area is not grazed by sheep or cattle, it is protected from fire, and a strip has been cut through it to get the timber out more easily, to afford ventilation, and to thin the trees. (Photo by L. S. Murphy, Courtesy U. S. Forest Service.)

4. *Pasturing* is another danger to forests. In our western forest preserves pasturing is allowed to too great an extent. Cattle and sheep eat off the young trees, and when the old ones are gone, or are cut, there are no young trees to take their places, and the land



ceases to be a forest. Much of our forest preserve territory has no trees on it, and it never will have until pasturing is stopped. Sheep are especially bad because they crop the grass so close that it is killed, and at the same time their sharp hoofs cut up the soil and start erosion which leaves gulleys where trees or grass should be. Where the surface soil is thus washed away, it may not be possible to get plants of any kind to grow again.



FIG. 314.—Sheep grazing in a national forest. Note the almost total absence of trees. It may be possible that more wealth is produced by using the land to feed sheep, but there will be no forest as long as the sheep are allowed to graze. (Photo by S. B. Locke, Courtesy U. S. Forest Service.)

5. *Fungus diseases* are also a menace. *Chestnut blight*, which we have mentioned before, is now found in nearly one half of the area where chestnut trees grow. Our chestnut forests seem to be doomed (Fig. 315). *White pine blister rust* is another disease which seems to be certain to kill what white pine remains, most of which has been cut.

6. *Insect pests* are another source of danger. We have mentioned the beetle in the Black Hills which has destroyed a billion feet of lumber. There are many other insects which damage trees in

one way or another. We can do little to protect the forest trees against them.

**Relation to Animals and Birds.**—If our forests are not protected, we can not keep many of our wild birds and animals. Even fish will be in danger. For many streams and lakes will go dry in summer if the forest is removed. The water will run off in the spring, and will not be held as it is now to be released all through the summer.

Our wild animals are valuable chiefly for their furs. If they must go, it may have a compensating advantage in stimulating the industry of breeding these animals in captivity for their pelts; but there is no such compensation in prospect for the loss of our wild birds.

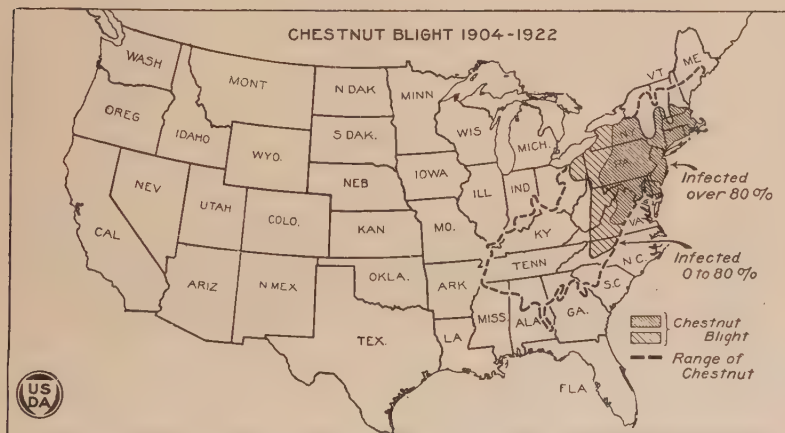


FIG. 315.—Chestnut blight has already wiped out chestnut over a large part of its range. (Courtesy U. S. Forest Service.)

## CARE OF SHADE AND ORCHARD TREES

**How to Transplant a Tree.**—Trees should be dug up carefully with their roots in the fall or early spring and replanted while the ground is moist and the weather cool. The hole should be larger than the root-mass and the soil used for filling the hole should be rich and finely divided (Fig. 316). If clay soil is used and water is poured into the hole, the soil will pack and prevent good root growth.

Before planting, the tree should be pruned so that the top is no more extensive than the root system. (See Fig. 317.)

When the young tree grew the roots and branches kept up a balanced condition between them. We can not take a tree out of the ground without breaking off many of the roots. If such a tree is set out with all of its branches and probably less than a third of its roots, the leaves and branches will not be supplied with as much water as they need. This may result in the tree withering and dying when the first hot and dry weather comes in summer. If the first summer is very dry and hot, the tree should be watered and perhaps more extensively pruned.

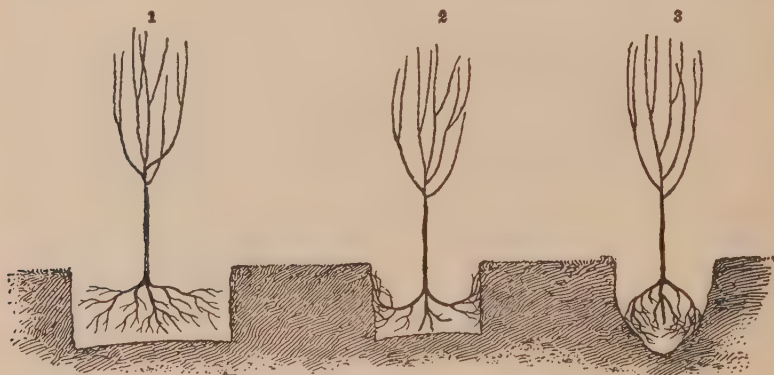


FIG. 316.—How to plant a tree. The hole of Fig. 1 is dug properly. What is wrong with each of the others? (U. S. Dept. of Agriculture.)

**Pruning.**—In the forest where trees grow close together the lower branches are shaded and die before attaining large size. This is called *self-pruning*. It is not profitable or necessary to prune trees in forestry projects; but park, shade, and fruit trees often require *trimming* to alter their shape, or *pruning* to remove dead wood or thin the branches. Do not destroy the natural shape and beauty of the tree (Fig. 318).

**In removing a large limb** a cut should be made from below first. If this is not done it may peel the bark down the side of the tree when it falls. When the limb is off the cut surface should slope so as to drain off the rain water and should be painted to keep out

the spores of fungus diseases. If the limb is cut close to the tree it will heal over more quickly than it will if a stub is left.

**Spraying** is not profitable in forestry projects, but it is a necessity in orchards, and may be profitable for shade trees. This subject



FIG. 317.—A sycamore trimmed for planting. Well pruned, without bad stubs. The dotted lines indicate which branches have been cut off. (*U. S. Dept. of Agriculture.*)

was discussed in the studies on fungus diseases of plants and insect pests.

**Protection against mechanical injury** from vehicles or the gnawing of horses is often advisable, for when the bark is peeled away,

a bad scar is left in which spores of fungus diseases may germinate, and which will require a long time to heal over.

**Tree surgery** is often resorted to to save an old tree which is diseased or injured. It is expensive work, and frequently leaves the



FIG. 318.—This is an example of how a tree should not be trimmed. It is a hickory tree the shape and beauty of which was spoiled because its owner wanted it to spread out, but the treatment was partly responsible for its death. It died the second summer after it was cut back.

tree to look like a cripple for many years. If the tree is diseased, it is generally better to remove it and set out a young and healthy one in its place. If the tree has a sentimental or historic value, tree surgery may be suggested as a means of prolonging its life.



## OUTLINE

The business of forestry.

Definition of forestry. The use of forest products.

The value of forests.

Classification of forest trees. Evergreens and deciduous trees.

Hard woods and soft woods. Which to plant.

Reproduction of forest trees. Seeds, root sprouts, coppice sprouts.

Forest conservation program. Fire protection, state assistance, improved taxation, forest loans, forest survey, land classification, government research, forest insurance.

Conservative lumbering.

Tree improvement.

Forest enemies. Lumbering, fires, agriculture, pasturing, fungus diseases, insect pests.

Forests and wild life. Birds, fish, animals.

Care of shade and orchard trees. Transplanting, pruning, trimming, spraying, mechanical protection, tree surgery.

**Review Questions.**—How should the business of forestry be carried out? What is forestry? How valuable is lumber? What part of our forests have been cut? What part is still forest land? Where is lumber needed the most? What states have the most timber left? What are the other values of forests? How are trees classified in reference to their use as lumber? Should we plant hard or soft woods in a forest project? Why? How do forests maintain themselves? What is the program of forest conservation? Which of the eight points will be the most difficult to work out in your opinion? How should trees be cut in scientific forestry? What has been done to improve trees by breeding? What are the enemies of forests? How does each do damage to the forest? How are animals and birds dependent upon forests? How should a tree be transplanted? How should a large limb be cut off? Of what value is tree surgery?

## SPECIAL ACTIVITIES

**Field Trips.**—Learn to recognize the common trees. Find out something about their life history and habits. What animals and birds inhabit them?

How are their seeds distributed? Collect samples of their leaves, fruits, and stems.

Observe the relation of trees to erosion.

Learn to recognize the common woods used in buildings and making furniture.

**Reports.**—What is veneer, and how is it made?

How rapidly has the price of lumber advanced in the past fifty years?

Where are the present lumber districts of the United States? What kinds of lumber do they contain? How much is left? See U. S. Forestry Bulletins.

### References

The best references on forestry are the bulletins of the U. S. Department of Agriculture. Write for a list and get those which you can use.

Otis, *Michigan Trees*, University of Michigan Press.

Emerson and Weed, *Our Native Trees*, J. B. Lippincott Co.

Pack, *Our Vanishing Forests*, Macmillan Co.

Jackson, *Forest Management*, Macmillan Co.

## PROBLEM 2. THE CONSERVATION OF OUR WILD FLOWERS AND GRASSES

**General Questions.**—Why are our wild flowers vanishing? How may they be saved? Should we ever pick wild flowers? What economic values have wild flowers? What values have our wild grasses?

“I believe in all the beautiful things of Nature, and would preserve, protect, and cherish them.” (*Nature Lover's Creed.*)

“What you would have appear in the life of the State, you must teach in the schools.” (*German proverb.*)

No country in the world has more natural beauty than America. The tourists slogan—“See America first”—implies that one need not go to the ends of the earth to observe nature in her grandeur or her simplicity. Whether it is rivers, lakes, plains, mountains, forests, or wild flowers that one wishes to enjoy, he can do no better than to see America.

The development of the automobile and the laying of concrete roads has brought each of us closer to the things of the out-of-doors than we ever were before; but it has brought a great danger. If the thousands of people who visit the beauty spots of nature in the fields, woods, and hills of our native land are not taught the simple prin-

ciples of conservation of nature's beauty, it will soon be spoiled, and some of it will never exist again.

Many of our wild flowers have been exterminated in the vicinity of our large cities. Not long ago the *showy lady-slipper* and the *yellow moccasin flower* bloomed in the shady woods for all to see and gather. Now there are none to be found. If we wish to observe them, we must go many miles and invade the forests where but few people can go. The *fringed gentian* and *blue harebell* were abundant in the restricted places where they were able to grow, but these spots have been visited year after year by those who knew their location, and each flower picked left none to take its place, for these flowers reproduce from seed only.

The flower which is threatened with extermination with a greater certainty than any other is the *arbutus*. It grows slowly, requiring a special type of soil, climate, and shade. It is one of the very first flowers of spring, and is one of the most fragrant of all flowers. The entire plant is frequently rooted up to obtain the blossoms. Because of its present rarity and its former abundance, it is greatly desired by those who have money to buy. It is sold in our large cities for fancy prices to those who do not know that they are contributing to the extinction of one of nature's gems.

We might mention many other flowers which are now scarce in places where they were formerly plentiful. Such plants are **wild forget-me-not, brown-eyed Susan, Jack-in-the-pulpit, columbine, shooting star, phlox, and the wild roses.**

The red fruits of the **wild prairie rose** stand up above the snow all winter, and are eaten by prairie chickens when little else can be found. The prairie chicken is almost extinct throughout the western prairie region where it was abundant in former years. Man has killed thousands of them, but this is not enough to cause their disappearance. Man has also killed their enemies by the thousands. Foxes, coyotes, badgers, skunks, wolves, large snakes, hawks, and owls are even more difficult to find in our western hills and valleys than is the prairie chicken. The chief reason why this valuable bird is going into extinction is that its natural food supply is gone. Where the roses left their red fruits for food there is nothing but the plowed wheat land. This is an example of the far reaching influences of the

destruction of any of the plants which grow in a balanced condition with other living things in nature. When we disturb nature's balance, we may cause forms to die or become more abundant than we never thought of affecting.

Those who appreciate our wild flowers and wish to keep them growing in their native glens and fields are forming clubs throughout the land to try to interest the public in their preservation. National efforts have been made to preserve our forests, game, fishes, and birds. The wild life which is in the greatest need of protection now, and which is not protected, is wild flowers. It may not be wise to urge that laws be passed to save them. Such laws would be difficult to enforce. More can be done by education than by any other method.

**The program for saving our wild flowers** may be outlined in the form of suggestions as to how to pick flowers. These appeals should be given the widest publicity. Will a committee of the class arrange to have these published in the local press every spring?

1. You are not asked to refrain entirely from picking flowers, but pick carefully and appreciatively.

2. Exercise the same care in picking wild flowers that you would in picking in your garden.

3. Do not pick the last few flowers from a plant or place, but leave them for seed.

4. Learn which flowers reproduce from seed and which from underground parts, and do not pull up the "roots" of perennials.

5. Do not pick wild flowers which are rare.

6. Never buy wild flowers from venders or flower shops.

7. Do not pick the leaves of a plant, for they are the organs where its food is made. If it is stripped of its leaves it may die.

8. Do not pick flowers which you do not intend to take home, and pick small bouquets.

9. Break or cut the flower stems. If you pull them the roots will be loosened and the plant may die.

**Wild grasses** are of as great value as are our native flowers or shrubs, but we seldom hear anything said about their preservation. It should be profitable to consider some of the values of wild grasses.

1. The chief use made of our grass lands is pasturage. Thousands of cattle, horses, and sheep feed upon native grasses throughout the summer. In some places too many animals have tried to live upon land which could not support them. The result is barren ground. If such unwise use of grass lands is continued, the soil becomes poor, the grass disappears, and rain water washes the surface soil away. After a time no grass will grow at all, and the land becomes deeply gullied and worthless. Sheep are the greatest offenders in the destruction of pasturage.



FIG. 319.—Gulleyed land which has lost its grass and other vegetation. Even this land may be planted with shrubs and some kinds of trees, but it will be difficult to restore it to grass land. (*U. S. Dept. of Agriculture.*)

2. Grass holds moisture and keeps the soil in good condition.
3. Grass roots hold the soil together. As long as grass grows green and strong the soil will not be blown away by wind, or washed away by water. Grass preserves the soil and its fertility (Fig. 319).
4. We must not forget the value to man of the beauty of a field or rolling prairie of grasses. We do not enjoy looking at the barren earth. The sand lands of Massachusetts, Kansas, Michigan, and Indiana may be beautiful to the tourist who calls them *sand dunes*



and views them as a unique geographical feature; but they are deserts. They produce no wealth, and would be more valuable if the soil were fertile and they were covered with grasses. Another example is the Bad Lands of South Dakota, and still another is the Great Western Desert lands. These lands have never had grasses on them in the memory of man, but there are grasses which will grow on sand land, even on sand dunes. If these grasses are cared for they will stop the drifting of the sand and save the adjacent farms which are being covered by the blowing sand.

5. To the naturalist the greatest interest of prairie lands is the protection which tall grasses afford to the many creatures which hide in them. Many birds, hundreds of insects and spiders, various snakes, frogs, and toads, as well as rabbits, gophers, mice, and other mammals live in the open fields and find their food and shelter there.

**Improvement of our grass lands** has received some attention in recent years. We have taken measures to avoid fires which are the worst menace, not only to the grasses but to the wild life which lives there. The burning of grass land to fight insect pests which the grass harbors is of little value because in the fall when the grass is dry enough to burn, the insects are gone or are beneath the surface of the ground and are not harmed.

**New grasses** have been imported with some success. Among these are *Bermuda grass* and *Sudan grass*, both of which grow rapidly and stand in dense formation in land which is suited to them. They are also a pest in land where they are not wanted.

### OUTLINE-SUMMARY

The beauties and wonders of America are in danger of being despoiled because of the reduction in numbers of our wild things and the development of the automobile which brings many people to the places where wild plants and animals are still to be found.

Many of our wild flowers are threatened with extinction in certain localities.

The partial extinction of the prairie chicken is an example of the effect on other forms of life of the destruction of a plant which is a source of food.

Education and public sentiment are better than laws in the campaign to save our wild flowers.

Program for saving our wild flowers.

Wild grasses are valuable as pasture land, to hold moisture and preserve the fertility of the soil, to prevent washing of the soil, for their beauty, and as a shelter to other living things.

Improvement of grass land.

Cultivation of new grasses.

**Review Questions.**—How does America compare with other nations in the grandeur of her lakes, forests, mountains, and other natural features? What danger does the automobile bring to our wild life? What flowers are becoming rare in some localities? How is the number of prairie chickens related to the number of wild prairie roses? Why is it dangerous to disturb the balance of nature? What do those who join clubs for the preservation of our wild flowers hope to accomplish? What precautions should be observed in the picking of wild flowers? What are the values of wild grasses?

#### References

- Blanchan, *Wild Flowers*, Doubleday, Page & Co.  
Francis, *Book of Grasses*, Doubleday, Page & Co.  
Comstock, *Handbook of Nature Study*, Comstock Pub. Co.  
Dana, *How to Know the Wild Flowers*, Chas. Scribner's Sons.  
Grey, *Manual of Botany*, American Book Co.  
Hitchcock, *Text-book of Grasses*, Macmillan Co.

#### PROBLEM 3. WHAT MAY BE DONE TO CONSERVE OUR FISHES?

**General Questions.**—Why do we know so little about the natural history of fishes? Do fishes have interesting life histories? Give some examples of the migration of fishes. What do fish eat? How should school aquaria be built? What fishes may be kept in them? What may be done with a fish pond on a farm? What is the economic importance of fishes? Describe the work of the U. S. Bureau of Fisheries.

After all that has been said about anglers and angling, two thirds of the line fishing of the world is done by boys. The boy may fish with a fly, but he does not spontaneously take to this method. Fly fishing is an art, a fine

art beyond a doubt, but it is an art and, like all art, it is artificial. Fishing with an angleworm is natural. It fits into the need of the occasion. It fits in with the spirit of the boy. (Holder and Jordan, *Fish Stories*.)

**Natural History.**—Because fishes live in water—often muddy water—they are not so easily observed as birds and insects; and the aver-



FIG. 320.—Sticklebacks and their nest. (From Basket, "*The Story of the Fishes*", D. Appleton & Co., New York.)

age person knows little about them, except how and where they may be caught, and what kinds make good eating. But in reality to those who have an opportunity to study them, their lives are very interesting. In beauty and display of colors some rival the most gorgeous birds and butterflies. In nest building and care of young

they have some interesting habits. For instance, there is the male stickleback which builds a hollow nest of water weeds and induces a female to lay eggs in it (Fig. 320). These he guards with great heroism until they hatch. If they are well fed and given an opportunity, they will build these nests in the school aquarium. The sunfish and bass make nests by hollowing out cavities in the sand. The male gaff-topsa'l-catfish takes the eggs of the female in his mouth and fasts for ninety days while they hatch. Young catfish remain together for some time after they hatch and are guarded by the male parent. The eggs of the top-water minnow, and of sharks, develop within the mother, and the young are brought forth alive.



FIG. 321.—The king salmon, also called the quinnat, and chinook salmon. (Calif. Fish and Game Commission.)

These are but samples of the varied lives led by fishes. If one will take the time, in the spirit of a true naturalist, he may learn many interesting things about fishes.

**Migration.**—Birds are not the only animals which migrate. The migrations of fishes are fully as remarkable. Most boys know how suckers run up the small streams to lay their eggs.

The king salmon of our Pacific coast grows to maturity in the ocean and ascends our western rivers to spawn when it is four years old (Fig. 321). It lays its eggs in November, and spends the entire summer preceding in ascending the river to its spawning place, often leaping high waterfalls. During the ascent no food is taken, and after spawning the fish floats down stream tail first until it dies.

The salmon of the Atlantic coast do not die after spawning but return to the ocean.

The eel reverses this method of migration. It spawns in the ocean and ascends rivers during the growing period of its life. A good account of its life history is given in the National Geographic Magazine of October, 1913. Will some member of the class read this article and report on it? Reports may also be made on the migrations of the striped bass, sturgeon, buffalo, and suckers. See bulletins of the U. S. Bureau of Fisheries.

The reasons why fishes migrate may be tabulated as follows:

1. In connection with breeding, to seek suitable places in which to lay their eggs.

2. In seeking food, they may venture out into streams and ponds, or those which live in the deep water may come to the shallow water along shore where food is more abundant.

3. In seeking wintering places. The carp lives in shallow water where vegetation is dense in summer and seeks out the depths in winter where they congregate in large numbers and remain inactive in a state of partial hibernation.

4. To distribute the species. This is the least voluntary of all and may be accidental. It occurs in spring when the rivers are at flood stage. Fishes wander over the flooded area and may be left in new situations when the water returns to the confines of the river banks.

**The food of fishes** varies with the species, the age of the fish, and the season of the year. The eel and carp eat the eggs of other fishes; therefore they should not be allowed to become too numerous. Fishes without sharp teeth are usually vegetable feeders. Examples of this group are suckers, buffalo, and carp; but these fishes eat animal food on occasion for variety. Fishes of the bass and pickerel type are almost wholly flesh eaters. Very small fishes usually feed on vegetable food, minute crustaceans, worms, and insect larvæ. As they get larger the carnivorous forms begin eating minnows which are smaller than themselves. "Big fish eat little fish", but the food problem of fishes depends upon the algal life of the water in which they live more than upon anything else, for it is in the green plant tissue that the food of the water world is elaborated, just as truly as is the



food of the life of the land. The quantity of fish which a pond will produce is dependent upon the amount of algæ which it can support. (See Figs. 21, 65, and 208.)

**Aquaria.**—We have discussed the balanced aquarium before and have shown how the plant and animal life which it contains mutually support each other. These facts should be reviewed at this time. Every biological laboratory should have an aquarium. It is convenient to have them built into the building in a well lighted place but where they can be protected from the direct rays of the



FIG. 322.—An aquarium in the department of biology of the Milwaukee State Normal school. Note that it is broad and shallow. It is at present the home of three turtles, two of which have been in captivity for eleven years.

sun by curtains. Running water is of value in some cases but by no means necessary if the light is suitable to the growth of vegetation. The tank need not be deep but should be wide so as to expose as much water-surface to the air as possible (Fig. 65). Why?

**The Fish Pond.**—A pond is a balanced aquarium on a large scale. There are many ponds in the United States which are capable of supporting aquatic life of great economic value which are yielding nothing. Get some copies of Bulletin No. 10, Pennsylvania Department of Fisheries, *What an Acre of Water Will Do* and study them.

According to this bulletin an acre of water may produce 5,000 to 6,000 pounds of fish per acre per year. What would this quantity of fish be worth?

Muskrats, clams, ducks, crayfish, frogs, water lilies, water cress, and basket willows may also be raised in and around the pond in properly limited numbers and further increase its annual profits.

**Economic Importance of Fishes.**—The United States, including her possessions, has about \$80,000,000 invested in the industry of fishing. Over 150,000 people are employed in the business, and the

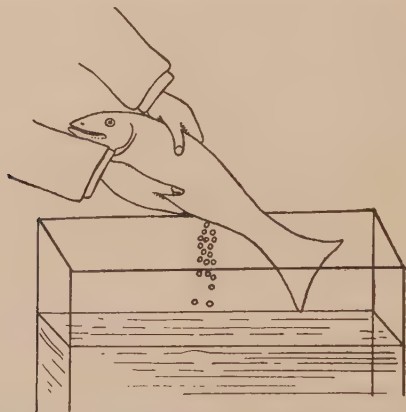


FIG. 323.—Diagram to show how eggs are pressed out of a fish in the process called stripping. The sperms from the male are collected in the same receptacle where fertilization takes place. (Holmes.)

products bring an annual return of \$125,000,000. Aside from this there is the sport fishing on both salt and fresh water. The great value of this in terms of health, recreation, and food is impossible to estimate accurately. Reports may be given on the methods of taking cod fish, salmon, and herring.

**U. S. Bureau of Fisheries.**—Fortunately we have not permitted our fishes to be destroyed as has been much of the life of the land, but the danger is not entirely passed. The several states have laws which protect the fishes of their local waters, and the Bureau of Fisheries is doing a great work, both along economic and scientific lines. The United States Government and various states maintain over fifty hatcheries where the eggs are removed from fishes by a

process called *stripping* (Fig. 323). The sperms of the males are placed over them by the same process, and then the entire mass is stirred with the tail of the fish or a stick. The adult fishes are then used as food or are returned to the water. The eggs are kept in trays until they hatch, and the young fishes are cared for until they are large enough to plant where they are to grow. Each year about four and one fourth billion eggs and young fishes are planted in American waters. Besides this a considerable number are shipped annually to foreign countries.

**Reports.**—Secure the latest bulletins on the subjects from the Bureau of Fisheries and find out what is being done for the lobster, blue crab, oyster, shrimp, and fresh water mussel.

### SUGGESTED SPECIAL ACTIVITIES

**Suggested Projects.**—Make up a list of the kinds of fishes in your community which can be kept in aquaria. Which kinds can be kept together? Which kinds require running water? What other animals can you keep in the aquarium? What plants? Why do crayfish, some snails, and most insect larvæ die if they are not permitted to come to the surface? An aquarium for keeping crayfish should be very shallow.

**Field Trip.**—Make collections which will enable you to work out the above projects and others which will present themselves to the interested student and teacher. If you have not done so before make a study of a pond and the life which it contains.

**Debate.**—Resolved that water farming is more profitable than land farming.

**Suggested Project.**—Is a pond available where a fish culture project can be worked out in coöperation with the owner? The author will be glad to receive information concerning the results of projects of this kind. Although carp have been domesticated in both Europe and Asia, very little practical, private fish culture has been attempted in America.

### OUTLINE

Natural history of fishes. Egg laying, nest building, care of young.

Food of fishes.

Aquaria compared to fish pond.

Economic importance of fishes.

Work of the Bureau of Fisheries.

Migration. Breeding, feeding, wintering, distribution.

**Review Questions.**—What percentage of line fishing is done by boys? How does the stickleback care for its eggs? What fishes migrate? Why do fishes migrate? What do fishes eat? What is the source of this food? How should a school aquarium be built? How may the ponds on farms be conserved and made useful? What may be raised in them? How much money is invested in the fishing industry? How are eggs collected and cared for by fish hatcheries? How extensive is this work?

#### References

The best references are the bulletins of the U. S. Bureau of Fisheries. Write for a list of recent ones.

Jordan and Evermann, *American Food and Game Fishes*, Doubleday, Page & Co.

Baskett, *Story of the Fishes*, D. Appleton & Co.

Holmes, *Animal Biology*, P. Blakiston's Son & Co.

Pearse, *General Zoology*, Henry Holt and Co.

Meehan, *Fish Culture in Ponds*, Macmillan Co.

#### PROBLEM 4. WHAT ARE THE VALUES OF BIRD LIFE?

**General Questions.**—What are our best game birds? How was the passenger pigeon exterminated? What birds are threatened with extermination? Are song birds valuable? Are crows and sparrows harmful? Are hawks and owls valuable? How may we protect our birds? How do cats rank as enemies of birds? How may we attract birds to our neighborhood?

**Game Birds.**—Man has hunted birds since prehistoric times. In the United States the most prized birds are the turkey, ducks, geese, snipe, woodcock, quail, and partridge. The most abundant game bird of the Continent was the passenger pigeon (Fig. 324). The following account of its abundance and destruction is taken from Knowlton's *Birds of the World*.

“The passenger pigeon presents one of the marvels of bird life. A century ago, when the country was new and less settled, this bird, so wonderful for its gregarious habits, existed in flocks of such gigantic proportions that the numbers appear absolutely incredible. Thus Wilson, one of America's pioneer ornithologists, writing about 1808, estimated that a flock observed by him near Frankfort, Kentucky, contained not less than 2,230,272,000 birds, and Audubon five years later saw them at Henderson in the same state passing for

three successive days in a practically continuous flock; 'the air was literally filled with pigeons, the light of noonday was obscured as by an eclipse', and the rush of wings was 'with a noise like thunder'. Their nesting places were necessarily of great extent. One described by Wilson near Shelbyville, Kentucky, was several miles in breadth and extended through the woods for upward of forty miles. Every tree of suitable size was loaded down with nests, a large hemlock, for example, often holding from twenty to forty.



FIG. 324.—Photograph of a male passenger pigeon which was killed in Wisconsin in 1872. Shortly after this date they became scarce.

"With the advent of the white man in this country, and the blessing of civilization the war upon the pigeon has been unceasing! Whenever a roosting or nesting place was discovered it was resorted to by a small army of despoilers, and with guns, poles, clubs, sulphur pots, and nets the work of destruction proceeded. Frequently from fifty to one hundred dozen were taken at a single throw of the net. At the large Michigan nesting it was estimated that five hundred netters were at work, and their average catch was 20,000 birds apiece, while for another resort it was estimated that hardly less than 1,000,000,000, including those dead and wounded but not secured, and the



myriads of squabs left dead in the nest, were 'sacrificed to Mammon' during a single year."

The last passenger pigeon has been killed, and this beautiful bird is gone forever. It is the greatest wild life tragedy of this continent. One of the reasons why the passenger pigeon was not protected was that they were thought of as pests, much as we think of crows and sparrows. They were very destructive to ripened grain, causing total losses of the crop before it could be placed in the bins in some cases.

We have had our lesson. There is small likelihood that we will permit another wild creature to be exterminated, if we can help it; but we may not be able to save some of the species which are now threatened, because their lives are adjusted to things as they were before man transformed this country into an artificial environment.

Among the birds which are now threatened with extinction are the upland plover, wood duck, woodcock, prairie chicken, California condor, and American eagle. If they are not fully protected and preserves provided for them where they may breed in safety, they will soon be extinct.

An attitude of civic righteousness should be cultivated in the hearts and minds of our people which would make the crime of wanton destruction of wild life a rare and disgraceful offense. There are some people who do not believe that education can accomplish this hoped for ideal, but we have made much progress. Wild ducks are protected on game preserves and pass through and rest in these areas on their migrations. Sometimes they may be seen in thousands, where they were not numerous before. Squirrels are more abundant in some of our cities where they are protected than they ever were in the wild state. Many forms of wild life become numerous with a fair amount of security assured by law or custom. Whether or not a bird like the sandhill crane can be saved by protection remains to be seen. This bird is seen rarely, and is nearly extinct.

**Song birds** are of value to man as insect eaters, weed-seed eaters, and as creatures to be studied and loved for their instincts, beauty, and songs. The United States Department of Agriculture has carried out extensive investigations to determine the economic value of our birds. Hundreds of bird's stomachs have been examined,

and the contents carefully noted and recorded. These investigations show that practically all birds are of value, and some are of great economic importance.

The crow, sparrow, blue jay, and various hawks and owls have been most severely accused by people who have suffered from their destructive acts or have observed them in a superficial way. The sparrow was brought to America in 1853 to destroy insects in our cities. This he does without reward. One summer the author watched a pair taking green caterpillars from his maple trees all day long, day after day until the insects were gone.

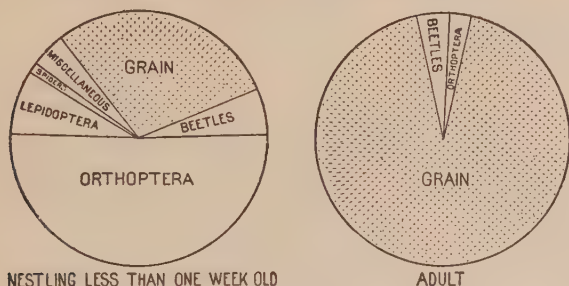


FIG. 325.—Diagram to show the proportions of food eaten by the English sparrow. Note that more than half of the food of the young is insects. Much of that listed as grain is weed seeds. (Judd.)

Our feeling toward the *crow* and *sparrow* is much the same as was that of our grandparents toward the passenger pigeon. How would we feel if they were exterminated? What bird will take the place of the sparrow in our cities if it is driven out? There is no bird which can live the life which our sparrow does, but defense of the sparrow is unnecessary. It is an excellent example of a species which man can not kill off. Wherever man builds his cities, the sparrow thrives. We have given up the foolish practice of trying to reduce their numbers by offering bounties to boys for killing them. The surplus of sparrows is killed off every winter by the weather. The bounty is wasted.

The *starling* is another European bird which thrives in our cities and is coming westward. The advance guard has reached Indiana, and it is only a question of time until it will be a companion to the sparrow, robin, blackbird, and meadow lark about our farms and

cities. What effect it will have on the lives of these birds is not known.

**Owls and hawks** are mostly beneficial (Figs. 326 and 327), but the American goshawk, Cooper's hawk, and the sharp-shinned hawk are pernicious. The pigeon hawk and the duck hawk are abundant only in certain localities where they probably do more harm than good. The sparrow hawk is a great insect eater but takes a small bird occasionally. Are hawks and owls protected in your state? Is a bounty offered for them?



FIG. 326.—Five pernicious hawks. All others are beneficial and should be protected unless they become too numerous. From left to right—duck hawk, Cooper's hawk, sharp-shinned hawk, goshawk, pigeon hawk.

The experience of Pennsylvania with this problem is interesting.

"In 1885, the rural feeling against hawks and owls reached the high-water mark in Pennsylvania. In response to the demands of the farmers of the state, the Pennsylvania legislature enacted a law providing a bounty of fifty cents for the heads of hawks and owls. Naturally, great slaughter of these birds ensued. In two years, 180,000 scalps had been brought in and \$90,000 had been paid out for them.

"The awakening came even more swiftly than the ornithologists expected. By the end of two years from the enactment of 'the hawk

law', the farmers found their fields and orchards thoroughly overrun by destructive mice, rats, and insects; and again they went clamoring to the legislature, this time for the quick repeal of the law. With all possible haste this was brought about; but it was estimated by competent judges that in damages to their crops 'the fool hawk law' cost the farmers of the state of Pennsylvania more than \$2,000,000'. (Hornaday.)



FIG. 327.—Owls destroy more mice than any other animal which still inhabits the settled districts of the United States except the king snakes and black snakes. Boys should be encouraged to protect owls. This is the short-eared owl with a mouse in its beak.

**Bird Protection.**—Much progress has been made along this line in recent years, but much remains to be done. The class should get into communication with the National Audubon Societies, and the American Ornithologists Union. They can help you, and you can help them.

*Song birds* are protected by state laws nearly everywhere. Public sentiment is strongly in their favor, but the removal of the forest and

the conversion of prairies into grain fields has changed living conditions. This is favorable to some forms and a misfortune for others, therefore some have increased in numbers and some have decreased.

*Game birds* are also protected by game laws. These laws are changed from time to time to keep up the average amount of game in localities where it is scarce. If quail are nearly exterminated in a region, no hunting is allowed until they are numerous again.

*A good treaty with Canada* has been ratified. This protects birds which migrate from Canada through the United States, but no treaty with Mexico, Cuba, or any of the countries of South America has been signed. This is desirable, but a treaty with these countries is not so necessary as the one with Canada.

*A national migratory bird law* has been passed. It affords protection to birds which pass from state to state whether each state gives protection or not. We may cite two cases to show the value of this law.

The *robin* is a favorite in the north, but on its migrations through some of the southern states, it was considered a game bird and was killed and made into potpies.

The *bobolink* is another favorite with people in the northern states, but in Carolina it is a bad pest in the rice fields. It passes through when rice is ripe and gathers its full share of the harvest. It is called the rice bird and is not at all welcome. Under the national law robins and bobolinks are protected throughout the nation.

*It is now unlawful to import the plumage of wild birds* into the United States, and the slaughter of birds for the decoration of the hats of thoughtless or heartless women has been checked, but it still goes on in some countries south of the United States which are not under our jurisdiction but where our migratory birds go.

*Public sentiment* in favor of the enforcement of these laws is as valuable as the laws themselves. Unless people are interested in protecting our birds the laws will do very little good. One of the aims of a course in biology is to stimulate public sentiment in favor of protecting our wild life.

*Cats* are the greatest enemies of our small birds. The average catch of each cat is fifty birds per year. The keeping of cats should be discouraged by education, and those who feel that they must keep



a cat should be required to pay for a license, and to attach a bell to the cat's neck to frighten birds in summer. Fortunately the



FIG. 328.—A cat at a bird box. Place your bird boxes where cats can not get at them.

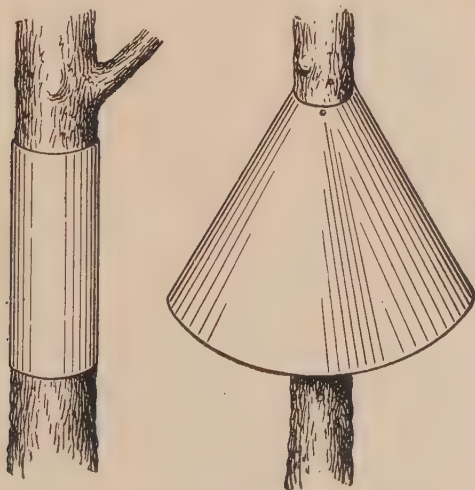


FIG. 329.—Two types of cat guards on trees. (*U. S. Dept. of Agriculture.*)

number of cats which are kept in cities is decreasing. Most people have come to the conclusion that they are not worth their keep.

**Attracting birds** to our homes, parks, and orchards is an enjoyable pursuit which is becoming more and more popular. The class should appoint committees to set up a bird bath, drinking fountains, and, in the winter, feeding tables may be arranged for our winter residents. Try to secure photographs of the birds as they come to these places. Hunt out their nests and place cat guards around the trees to protect the young. Photograph the nests and young, and try to have the photographs published.

Many kinds of shrubs which produce berries may be planted to furnish both homes and food for birds which do not readily nest in cities. The following list of small fruits is taken from Bulletin No. 715 of the Bureau of Biological Survey.

| Common name                     | Scientific name       | Number of species of birds known to eat the fruit | Common name                | Scientific name           | Number of species of birds known to eat the fruit |
|---------------------------------|-----------------------|---------------------------------------------------|----------------------------|---------------------------|---------------------------------------------------|
| Juniper; red cedar.             | <i>Juniperus</i> ...  | 36                                                | Pepperberry....            | <i>Schinus</i> .....      | 10                                                |
| Greenbrier.....                 | <i>Smilax</i> .....   | 38                                                | Holly.....                 | <i>Ilex</i> .....         | 38                                                |
| Bayberry.....                   | <i>Myrica</i> .....   | 64                                                | Supple-jack....            | <i>Berchemia</i> .....    | 12                                                |
| Hackberry.....                  | <i>Celtis</i> .....   | 38                                                | Buckthorn.....             | <i>Rhamnus</i> .....      | 16                                                |
| Mulberry.....                   | <i>Morus</i> .....    | 52                                                | Grape.....                 | <i>Vitis</i> .....        | 71                                                |
| Pokeberry.....                  | <i>Phytolacca</i> ... | 48                                                | Virginia creeper..         | <i>Parthenocissus</i> ... | 39                                                |
| Barberry.....                   | <i>Berberis</i> ..... | 10                                                | Buffaloberry....           | <i>Shepherdia</i> .....   | 13                                                |
| Spicebush.....                  | <i>Benzoin</i> .....  | 17                                                | Wild sarsaparilla.         | <i>Aralia</i> .....       | 14                                                |
| Sassafras.....                  | <i>Sassafras</i> .... | 15                                                | Dogwood.....               | <i>Cornus</i> .....       | 79                                                |
| Currant; goose-<br>berry.....   | <i>Ribes</i> .....    | 30                                                | Sour gum.....              | <i>Nyssa</i> .....        | 36                                                |
| Strawberry.....                 | <i>Fragaria</i> ..... | 42                                                | Bearberry.....             | <i>Arctostaphylos</i> ... | 12                                                |
| Raspberry; black-<br>berry..... | <i>Rubus</i> .....    | 114                                               | Huckleberry....            | <i>Gaylussacia</i> .....  | 30                                                |
| Rose.....                       | <i>Rosa</i> .....     | 17                                                | Blueberry.....             | <i>Vaccinium</i> .....    | 62                                                |
| Mountain ash....                | <i>Sorbus</i> .....   | 14                                                | Mexican mul-<br>berry..... | <i>Callicarpa</i> .....   | 10                                                |
| Chokeberry.....                 | <i>Aronia</i> .....   | 13                                                | Partridge berry..          | <i>Micthella</i> .....    | 10                                                |
| Red haw.....                    | <i>Crataegus</i> ...  | 30                                                | Elder.....                 | <i>Sambucus</i> .....     | 101                                               |
| Juneberry.....                  | <i>Amelanchier</i> .  | 38                                                | Snowberry.....             | <i>Symphoricarpos</i> ..  | 22                                                |
| Cherry; plum....                | <i>Prunus</i> .....   | 66                                                | Black haw.....             | <i>Viburnum</i> .....     | 26                                                |
| Sumach.....                     | <i>Rhus</i> .....     | 76                                                | Honeysuckle....            | <i>Lonicera</i> .....     | 15                                                |

**Bird houses** have been built by boys from the dawn of written history, but there never has been so many bird houses as now. The types of structures which are built are of many designs, and are

| Species                        | Floor of cavity | Depth of cavity | Entrance above floor | Diameter of entrance | Height above ground |
|--------------------------------|-----------------|-----------------|----------------------|----------------------|---------------------|
|                                | <i>Inches</i>   | <i>Inches</i>   | <i>Inches</i>        | <i>Inches</i>        | <i>Feet</i>         |
| Bluebirds.....                 | 5 × 5           | 8               | 6                    | 1½                   | 5-10                |
| Robin.....                     | 6 × 8           | 8               | (1)                  | (1)                  | 6-15                |
| Chickadees.....                | 4 × 4           | 8-10            | 6-8                  | 1½                   | 6-15                |
| Titmice.....                   | 4 × 4           | 8-10            | 6-8                  | 1¼                   | 6-15                |
| Nuthatches.....                | 4 × 4           | 8-10            | 6-8                  | 1¼                   | 12-20               |
| House wren.....                | 4 × 4           | 6-8             | 1-6                  | ¾                    | 6-10                |
| Bewick wren.....               | 4 × 4           | 6-8             | 1-6                  | 1                    | 6-10                |
| Carolina wren.....             | 4 × 4           | 6-8             | 1-6                  | 1½                   | 6-10                |
| Violet-green swallow.....      | 5 × 5           | 6               | 1-5                  | 1½                   | 10-15               |
| Tree swallow.....              | 5 × 5           | 6               | 1-5                  | 1½                   | 10-15               |
| Barn swallow.....              | 6 × 6           | 6               | (1)                  | (1)                  | 8-12                |
| Purple martin.....             | 6 × 6           | 6               | 1                    | 2½                   | 15-20               |
| Song sparrow.....              | 6 × 6           | 6               | (2)                  | (2)                  | 1-3                 |
| House finch.....               | 6 × 6           | 6               | 4                    | 2                    | 8-12                |
| Starling.....                  | 6 × 6           | 16-18           | 14-16                | 2                    | 10-25               |
| Phoebe.....                    | 6 × 6           | 6               | (1)                  | (1)                  | 8-12                |
| Crested flycatcher.....        | 6 × 6           | 8-10            | 6-8                  | 2                    | 8-20                |
| Flicker.....                   | 7 × 7           | 16-18           | 14-18                | 2½                   | 6-20                |
| Golden-fronted woodpecker..... | 6 × 6           | 12-15           | 9-12                 | 2                    | 12-20               |
| Red-headed woodpecker.....     | 6 × 6           | 12-15           | 9-12                 | 2                    | 12-20               |
| Downy woodpecker.....          | 4 × 4           | 8-10            | 6-8                  | 1¼                   | 6-20                |
| Hairy woodpecker.....          | 6 × 6           | 12-15           | 9-12                 | 1½                   | 12-20               |
| Screech owl.....               | 8 × 8           | 12-15           | 9-12                 | 3                    | 10-30               |
| Saw-whet owl.....              | 6 × 6           | 10-12           | 8-10                 | 2½                   | 12-20               |
| Barn owl.....                  | 10 × 18         | 15-18           | 4                    | 6                    | 12-18               |
| Sparrow hawk.....              | 8 × 8           | 12-15           | 9-12                 | 3                    | 10-30               |
| Wood duck.....                 | 10 × 18         | 10-15           | 3                    | 6                    | 4-20                |

<sup>1</sup> One or more sides open.

<sup>2</sup> All sides open.

FIG. 330.—Dimensions of nesting boxes for various species of regular box-inhabiting birds and the height at which they should be placed above the ground. (*Farmers' Bulletin* 1456.)

accepted as nesting sites by 45 different kinds of birds as reported in *Farmers' Bulletin* 1456. They are listed in the table which is taken from that bulletin.

|                            |                            |
|----------------------------|----------------------------|
| Mountain bluebird.         | English sparrow.           |
| Western bluebird           | House finch.               |
| Eastern bluebird.          | Purple grackle.            |
| Robin.                     | Orchard oriole.            |
| Chestnut-backed chickadee. | Starling.                  |
| Mountain chickadee.        | Phoebe.                    |
| Carolina chickadee.        | Ash-throated flycatcher.   |
| Black-capped chickadee.    | Crested flycatcher.        |
| Plain titmouse.            | Red-shafted flicker.       |
| Tufted titmouse.           | Yellow-shafted flicker.    |
| Red-breasted nuthatch.     | Golden-fronted woodpecker. |
| White-breasted nuthatch.   | Red-headed woodpecker.     |
| Brown creeper.             | Downy woodpecker.          |
| House wren.                | Hairy woodpecker.          |
| Bewick wren.               | Screech owl.               |
| Carolina wren.             | Saw-whet owl.              |
| Brown thrasher.            | Barn owl.                  |
| Violet-green swallow.      | Sparrow hawk.              |
| Tree swallow.              | Mourning dove.             |
| Barn swallow.              | Wood duck.                 |
| Cliff swallow.             | American goldeneye.        |
| Purple martin.             | Hooded merganser.          |
| Song sparrow.              |                            |

How many of the members of the class have bird boxes?

Has anyone any interesting experiences to relate concerning them? Girls should be as much interested in bird boxes as boys. Can you make some boxes in the manual training department? The author visited a school a short time ago where all boys in the school system were invited to make bird boxes and exhibit them. The public was invited in to see them, and the best ones were awarded prizes. Would this be profitable in your school? If so, appoint a committee to investigate ways and means of making it a success.

#### OUTLINE

Game birds, the passenger pigeon, game preserves.

Song birds, crow, sparrow, starling.

Owls and hawks, their economic value.

Bird protection, song birds, game birds, treaty with Canada, migratory bird law, migration and slaughter of robin and bobolink, importation of bird plumage, public sentiment.

Cats as enemies of birds.

Attracting birds, bird homes, feeding birds, bird home building contest.



FIG. 331.—A good house for purple martins. They may live in colonies of 25 or more. The house should be divided into rooms each of which has an outside door. (*U. S. Dept. of Agriculture.*)

**Review Questions.**—Tell the story of the extermination of the passenger pigeon. What do we learn from this tragedy? What other birds may become extinct soon? What is being done to prevent it? What is the standing of the sparrow? How is the starling thriving in America? What good and harm do owls and hawks do? What would happen if they were destroyed? How are our birds protected? Can laws do good if they are contrary to public sentiment? What is the relation of cats to birds? Describe the ways of attracting birds.



## References

The best references are the bulletins of the U. S. Department of Agriculture. Write for a list and secure what you need. The list is constantly changing, and any that might be suggested here would probably be superseded in a short time.

Holmes, *Animal Biology*, P. Blakiston's Son & Co.

Mosley, *Trees, Stars, and Birds*, World Book Co.

Trafton, *Bird Friends*, Houghton Mifflin Co.

*New Nature Library*, Doubleday, Page & Co.

Lange, *Our Native Birds*, Macmillan Co.

Reed, *Bird Guide*, Doubleday, Page & Co

Baynes, *Wild Bird Guests*, Dutton.

## UNIT XI. SOME GREAT BIOLOGISTS AND THEIR CONTRIBUTIONS TO BIOLOGY

In his brief sketch it will be impossible to mention but few of the hundreds of zoologists, botanists, physiologists, and biologists who have given the labor of their lives to the advancement of this great science. We owe to them much of what we know and have to-day. Merely to mention the progress which has been made in the understanding of the nature and cause of disease, is enough to remind us of this debt. We shall consider only a few of those who represent leadership in the development of special lines of progress. It should be remembered that in no case was one man responsible for all of the information which was collected to establish an important theory or fact.

**Aristotle (384-322 B.C.), the First Biologist.**—The Greeks knew much about plants and animals, but much of what they thought they knew was not true. Aristotle wrote three important books,—*The History of Animals*, *The Generation of Animals*, and *The Parts of Animals*. He attempted a classification of animals and was the first to use the word “genus” to indicate a natural group of species, but he knew very little about the internal structure of the kinds which he tried to classify, and for this reason his system was imperfect.

**The anatomists** were the real founders of the science of biology. The structure of man and nearly all plants and animals has been studied so that now we have an extensive knowledge of each group. This information was necessary before a good system of classification could be worked out. One of the earliest anatomists was **Galen**, born A.D. 130. Perhaps the next man to deserve mention was **Versalius**, who made most accurate accounts of human anatomy.

During 1851-58 **Conrad Gesner** published his *History of Animals* which comprised 4,500 folio pages and numerous illustrations. It contained descriptions and illustrations of dragons, hydras, basilisks, and sea serpents which did not exist, but it also contained some very accurate accounts. From this time on there were so many anato-

mists that we can not mention them here, but we should give place to **William Harvey** who discovered that the blood of animals circulates, that the heart pumps it, and that the valves of the heart are to keep it from flowing back again. He made this discovery in 1616 and published the fact in 1628. Previous to this it was supposed that the heart was the seat of the emotions, and that the arteries were filled with air. He did not discover the capillaries, because the microscope had not been invented, and he did not know just how blood returned to the heart. He also announced the fact that all animals develop from eggs, in dispute of the *theory of spontaneous generation*, but he thought that an egg might arise spontaneously (without a parent).

The microscopists began their contributions to biology when **Hans and Zacharias Janssen** invented the microscope during the years 1590-1600. This led to the development of the *cell theory* which states that all plants and animals are composed of cells and the products of cells. This line of research culminated in the work with bacteria by **Pasteur** and others between 1870 and 1890 which

established bacteria as the cause of contagious disease. The first man to name the cell as the unit of structure of living things was **Robert Hooke**.



FIG. 332.—John Ray, 1628-1705).

**Linnæus (1707-1778) the Great Classifier.**—The science of Classification was started by Aristotle, but it made no progress until **John Ray**, an English Clergyman, published a system of classification, based on anatomy. This was a few years before the birth of Linnæus. He was the first to distinguish between mono- and dicotyledonous plants, however the vast amount of work done by Linnæus gives

him first place among all classifiers. He organized the system which we now have, and suggested the use of a generic and specific name to designate each plant and animal. He tried to see that every living thing was named according to his system which has been accepted by all biologists. His last work, published after his death, contained ten volumes. (See Fig. 192.)

**Lamarck** was the first to use the term "biology" to include both plants and animals. He believed that species were not fixed as did nearly all biologists before him. He thought that species changed as a result of the action of the environment upon individuals which adapted themselves to it. These adaptive changes were "accumulated" in the reproductive tissues and passed on to the next generation. This theory, which he announced in 1809, is known as the *theory of inheritance of acquired characteristics*.

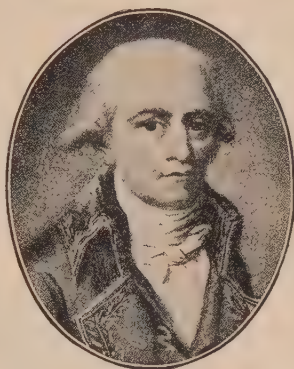


FIG. 333.—Jean Baptiste Lamarck (1744-1829).

**Weismann** did not accept Lamarck's theory of inheritance, and performed a simple but long experiment to disprove it. This project has become one of the most famous of all biological experiments. He cut the

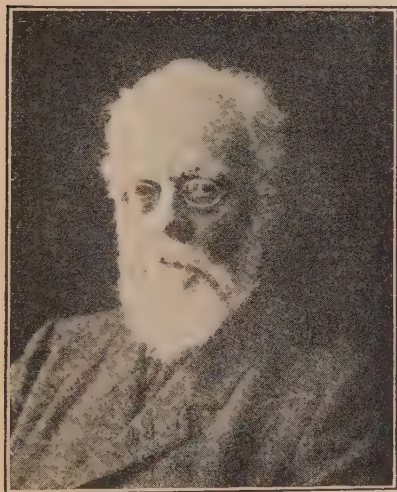


FIG. 334.—August Weismann (1834-1916). (Keystone View Co.)

tails off of mice as soon as they were born, for many generations, to see if their tails would be lost or shortened by their disuse. When the tails were allowed to grow they were as long as they were at the start of the experiment. Many other experiments of the greatest variety of types have been performed, but in no test has any one been able to establish an undisputed case of the permanent inheritance of a character which was acquired by an animal or plant due to the action of use, disuse, or environment. This has made Weismann the greatest theorist in the field of heredity, and has completely set aside the theory of Lamarck that an acquired charac-

teristic can be inherited. It means a great deal to us to know that what we lose or develop will not be lost or gained to the next generation through heredity. It means that the giraffe did not acquire a long neck by stretching it, that the sun did not turn the negro black, that it is not true that the blind fish is without eyes because its ancestors did not use theirs, or that the son of a blacksmith will have a stronger right arm because his father swung a heavy hammer.

**Georges Cuvier** (1769-1832), the founder of the study of fossils, was a French zoologist who lived at the time of Lamarck and opposed Lamarck's idea that species changed. Cuvier did show that the life of the past was much different from the life of the present, but he believed that ancient forms had been killed off by some great calamity at various periods which corresponded to the epochs of time. This theory was destroyed when **Sir Charles Lyell** published his *Principles of Geology* in which he stated that the life of each geologic epoch had descended from the life of the preceding epoch, and that there was no special creation of new types of life at the beginning of each division of time. This was the *theory of descent*. It replaced Cuvier's *theory of periodic creation*.

**Natural selection** is the name of a theory which attempts to explain what Lamarck failed to account for, namely, the method by which plants and animals change. This theory was announced successively by **W. C. Wells** in 1813, **Patrick Matthew** in 1831, and by **Alfred Russel Wallace** and **Charles Darwin** in 1858. The early statements of it were clear but very brief. The great amount of researches and writings of Darwin have won for him the chief credit for this important biologic theory.

In an effort to make this theory more easily understood we shall state it in the form of a formula as follows:

- |                   |   |                                                                                                                                                                                       |
|-------------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Natural selection | { | <ol style="list-style-type: none"> <li>1. Variation</li> <li>2. Overproduction</li> <li>3. Struggle for existence</li> <li>4. Survival of the fittest</li> <li>5. Heredity</li> </ol> |
|-------------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

We may call this the *formula of natural selection*. Some comment on each of its five elements is necessary.



1. **Variation** is a generally accepted fact. Statistical studies have shown that a species so uniform as the English sparrow varies considerably in wing length, bill length, toe length, color, etc.

2. **Overproduction.**—The female codfish lays from two to eight million eggs per year. If they should all hatch and reach maturity, and continue to reproduce at that rate, “the ocean would soon be so full of fish that there would be no room for the water!” Obviously, they can not all survive. Actually, there is, on the average, only one pair produced to replace each pair which dies. This means that

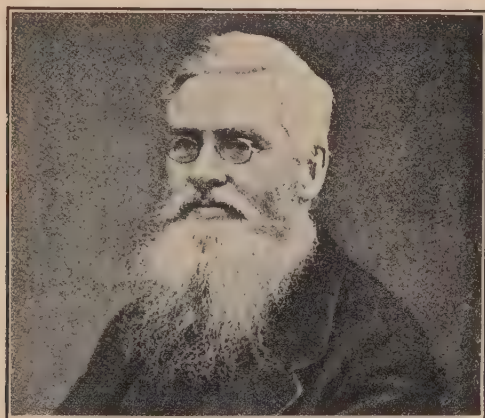


FIG. 335.—Alfred Russel Wallace (1823-1913).

millions must die of under-nourishment or fall a prey to their enemies. All life would overproduce itself in a very short time if it were free to multiply to an unlimited extent. Even the elephant which does not produce more than one calf in three years would overrun the earth in one century if it were not checked.

3. **Struggle for Existence.**—Among the abundant offspring of any species there is a contest, or struggle, to live and to reproduce the species. This contest may be for room, for food, against enemies or the forces of nature, or among individuals of the same species. Among plants it is a passive struggle; but it is, nevertheless, very intense. One needs but to go into the woods and note the dead

branches killed by shading, or the tall saplings, or the abundant shade plants to realize how rigorous this struggle is.

4. **Survival of the fittest** means that in the struggle those which are the most fit to win and survive will probably do so. It does not mean that all fit will survive, for unavoidable misfortune may overtake some, but on the average, those which have physical and mental advantages will stand a better chance, and over a long period of time, and counting many individuals, more of the fittest will endure to reproduce their kind.

5. **Heredity.**—It is here that heredity is called upon. The fortunate variations must be preserved by heredity if the next generation

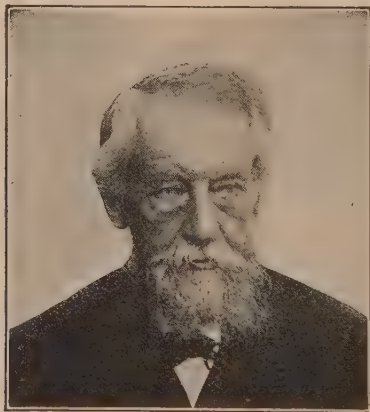


FIG. 336.—Hugo de Vries, Dutch botanist and student of variations (1848– .)

is to be different from, and better fitted to, the environment than the one which went before. Thus nature selects the fittest to reproduce the race, and slowly, very slowly, changes the life of the earth as the environment changes. If environment stood still there would be little change in the characteristics of species of plants and animals.

*Natural selection* and the *inheritance of acquired characteristics* are both theories of species changes by action of environment, but in the first environment produces no direct changes in the next generation. It merely cuts off, kills, or permits to die those plants and animals which are not well fitted to it. In the second, characters which

are acquired by action of environment, as a coat of tan, or an education are supposed to be inherited cumulatively. Natural selection is a sound theory, but the other, as we have said before, is not supported by evidence.

**Variation and heredity** were not understood until the beginning of the present century. We have described the experiments of **Mendel** on garden peas, and have shown how they were the foundation of the three laws of heredity which are known as *Mendel's laws*.

The greatest student of variation was **Hugo de Vries** of the Netherlands. He advocated the *theory of mutations* to account for many



FIG. 337.—Luther Burbank (1849-1926). (*Keystone View Co., New York.*)

of the changes which have taken place in plants and animals. Mutations were discussed in the studies on plant and animal breeding.

It was about this time that chromosomes were discovered and very extensively studied by many careful microscopists. We discussed them in our studies on the cell. As a result of this work the *chromosome theory* was advanced as the cause of variations. It holds that all hereditary variations arise in the chromosomes by accidental and mechanical variations in the chromosomes themselves at the times when they are splitting in cell division. At the present time it is

not possible to accredit the discovery of chromosomes as the cause of variation to any one man. These great discoveries in the field of variation and heredity have been valuable in advancing the science of plant and animal breeding.

**Luther Burbank (1849-1926)** is the outstanding figure among hundreds of men who have improved our domestic plants and animals in recent years. Some of the work which has been done, and

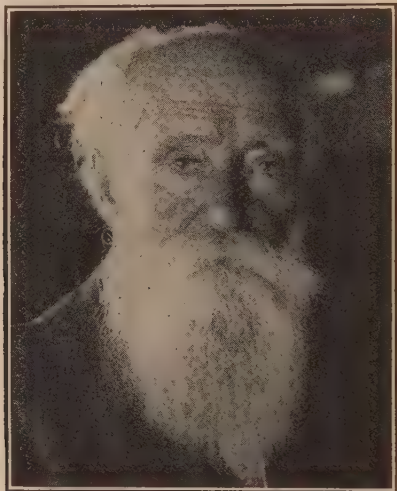


FIG. 338.—John Burroughs (1837-1921). (*Keystone View Co., New York.*)

the methods which are used have been discussed in the studies on plant and animal breeding.

**John Burroughs (1837-1921), the Great Nature Student.**—A love of, and an appreciation for, nature has had a great awakening in modern days. Of the many able men and women who have been prominent in this work Burroughs easily leads the list. He wrote many books, and fought for the protection of our wild life with great success. Many keen and accurate observers have added much valuable information to our store of knowledge of the lives of the wild plants and animals. The more of this knowledge we have, the greater is our capacity to enjoy nature.

## GLOSSARY

The alphabetic sound of the letters has been the key for the phonetic pronunciation. Only where a doubt might arise has a diacritic mark been used. Example:

ū is sounded as in pure.

ǣ as in mate.

ō as in old.

**Abdomen** (Lat. *belly*) (ab dō' men): The part of the body which contains the intestine.

**Absorption** (Lat. *absorbere*, to swallow) (ab sorp' shun): The process of taking digested food into the body.

**Accessory fruit** (Lat. *accessus*, increase) (ak ses' so re): A fruit with an enlarged receptacle.

**Adaptation** (Lat. to fit) (ad' ap tā' shun): Ability of living things to become fitted to their environments.

**Adenoids** (Gr. gland) (ad' en oid): Growths in the nasal passages which interfere with breathing.

**Æolian soils** (Æolus, God of winds) (e o' le an): Soils which have been transported by the wind.

**Aggregate fruit** (Lat. *gregare*, to collect into a herd) (ag' gre gate): A fruit having its carpels assembled on a common receptacle.

**Akene** (ah kēn'): A dry fruit bearing one seed; also spelled achene.

**Albinism** (Lat. *albus*, white) (al' bin iz m): The absence of pigments in skin, hair, feathers, and eyes.

**Albumen** (Lat. *albus*, white) (al bū' men): Protein food stored in seeds, or one of the most complex of the protein groups.

**Al'cohol**: An intoxicating poison.

**Alga**, pl. *algæ* (Lat. seaweed) (al' ga, al' je): The simplest of the four great groups of plants.

**Alimentary canal** (Lat. *alimentum*, food) (al' e men ta re): The entire tube through which the food passes during digestion.

**Alkaloids** (alkali + oid) (al' ka loid): Organic bases which are usually harmful to living tissues.

**Allantois** (Gr. *allas* + *eidōs*, sausage-like) (al lan' to is): An embryonic structure which serves as a respiratory organ in embryos and becomes the urinary bladder in adults.

**Alluvial soil** (Lat. *alluvio*, to wash against) (al lu' ve al): Soil deposited by water.

**Amino acid** (am e' no): An acid containing a nitrogen atom linked with two atoms of hydrogen.

**Amphibian** (Gr. *amphi*, both + *bios*, life) (am fib' e an): Any one of the allies of the frogs and salamanders.



- Amphimixis** (*amphi*, both + *mixi*, mingle) (am fe' mix is): A theory of variation which ascribes the cause of variation to the differences in the two parents.
- Amylopsin** (Gr. *amyl*, starch) (am' il op' sin): A starch-digesting enzyme produced by the pancreas.
- Anaphase** (an' af aze): A stage in cell division wherein the chromosomes pass from the middle to the ends of the spindle.
- Anesthetic** (Gr. without feeling) (an' es thet' ik): A substance which is capable of rendering one insensible to pain.
- Angiosperm** (Gr. *aggeion*, vessel + *sperma*, seed) (an' je o sperm): A plant which bears its seeds in an ovary.
- An'nual**: A plant which lives only one year.
- An'nual rings**: Rings of growth in a tree-stem.
- An'nulus** (Lat. *annulus*, a ring): A ring of thick cells in the spore case of a fern.
- Antenna**, pl. **antennæ** (Lat. *antenna*, sail yard) (an ten' na; ten' e): The feelers of insects and other arthropods.
- Anten'nule** (ūl): A small antenna.
- Anther** (Gr. *antheros*, flowery) (an' ther): The pollen-bearing portion of a stamen.
- Antheridium** (anther + Gr. diminutive *idion*) (an' ther id' e um): A plant structure in which sperms are produced.
- Antidiphtheric serum** (an te dif ther' ik): An antitoxin of use in combatting diphtheria.
- Antitoxin** (Lat. *anti*, against + *toxicum*, poison) (an te toks' in): A substance prepared by living tissues which counteracts some poison.
- Antiseptic** (Gr. *anti*, against + *sepsis*, putrefaction) (an te sep' tik): A substance which is poisonous to microorganisms.
- Apiary** (Lat. *apis*, bee) (a' pe a re): A place where bees are kept.
- Appendix** (Lat. to hang to) (ap pen' diks): A protruding tube or sac at the junction of the large and small intestines.
- Aquarium** (Gr. water) (a kwa' re um): A vessel in which aquatic plants or animals are kept.
- Arachnid** (Gr. spider) (a rak' nid): Any one of the group of spiders and scorpions.
- Archegonium** (Gr. *arche*, beginning + *gone*, race) (ar ke go' ne um): An organ of plants in which eggs are developed.
- Ar' tery**: A blood vessel which conveys blood from the heart.
- Arthropoda** (Gr. jointed feet) (ar throp' o da): The insects, crustaceans, spiders, and their allies.
- Artificial selection**: Plant and animal breeding wherein man chooses for breeders those animals or plants which have special characteristics.
- Asex'ual spore**: A spore which is produced without conjugation or fertilization.
- Assimila'tion** (Lat. *assimilare*, to make alike): The process of taking in food and making it a part of the living plant or animal.
- Atavism** (Lat. *atarvus*, an ancestor) (at' av iz m): The appearance of grand-parental characteristics in an individual. Reversion is inheritance from very remote ancestors.

- Atom:** The smallest unit particle of a chemical element.
- Bacteria** (Gr. *bakterion*, a small rod) (bak te' re ah): Simple fungus plants which are microscopic in size and produce disease and decay.
- Bast:** The fibrous part of the bark.
- Bi, bis, di:** Lat. prefixes meaning twice.
- Biennials** (Lat. two rings) (bi en' e al): Plants which live through parts of two summers.
- Biogenetic law** (bi o jen et' ik): Same as recapitulation theory.
- Biology** (Gr. *bios* + *logos*, a discourse on life) (bi ol' o je): A scientific study of living things.
- Blastula** (Gr. *blastos*, a sprout or bud) (blas' tū la): A stage in the embryology of an animal wherein the cells are arranged in the shape of a hollow ball.
- Bract** (Lat. *bractea*, a thin plate): A modified leaf which protects a flower.
- Breeding:** Propagating and improving domestic plants and animals.
- Bud variation:** Bud mutation.
- Budding:** A form of multiplication in yeast. A form of grafting in horticulture.
- Bud:** An undeveloped shoot.
- Bulb:** An undeveloped underground shoot.
- Bulb'let:** A small bulb.
- Bur:** A fruit or seed possessing spines or hooks.
- Calyptra** (Gr. *calyptera*, veil) (kal ip' trah): A hood, formed from the archegonium, over the capsule of a moss.
- Calyx** (Gr. *calyx*, a cup) (kal' iks): The leaf-like parts of a flower which surround and enclose the petals.
- Cam'bium** (Lat. exchange): The cells of a stem which produce phlōem on their outer side and xylem on the inner.
- Capillarity** (Lat. *capillus*, hair) (kap il lar' it e): The ability of water to rise, against gravity, in tubes of fine bore, soil, etc.
- Capsule** (Lat. *capsula*, a small box) (kap' sūl): The spore case of a moss, or a dry fruit of more than one locule.
- Carbohydrate** (carbon + water) (kar bo hī' drate): A chemical compound of carbon, hydrogen, and oxygen wherein the hydrogen atoms are twice the oxygen atoms.
- Car'pel** (Gr. *carpos*, fruit): A compartment in a pistil in which seeds are formed.
- Cat'kin:** A pendent inflorescence, like a cat's tail.
- Caulicle** (Lat. *caulis*, stem) (kaw' lik el): A little stem of a seedling.
- Cell** (a chamber): A portion of protoplasm containing a nucleus when young at least and usually surrounded by a membrane.
- Cell tur'gor** (Lat. *turgidus*, swollen): Sap pressure in a cell which gives it firmness.
- Cellulose** (from cell) (sel'-u-lōse): The woody material of which the walls of plant cells are made.
- Chlorophyll** (Gr. *chloros*, green + *phyllon*, leaf) (klo' ro fil): The green substance in plants in which photosynthesis takes place.
- Chloroplast** (klo' ro plast): Small bodies in plants in which chlorophyll is confined.

- Chordata** (Lat. *chorda*, cord, notochord) (kor day' tah): Animals having a notochord.
- Chorion** (Gr. membrane) (koh' ree on): An embryonic membrane which surrounds the young of the higher vertebrates before birth.
- Chromoplast** (Gr. *Chroma*, color + *plastos*, moulded) (kro' mo plast): A colored body in plant tissues which contains coloring matter other than chlorophyll.
- Chromosome** (Gr. *chroma*, color + *soma*, a body) (kro' mo sōm): One of the bodies of the nucleus which manifests itself during cell division.
- Cil'ium**, pl. *cilia* (a hair) (sil' e um; e ah): A hair-like projection from a cell.
- Cœlenterata** (Gr. *koilos*, hollow + *enteron*, intestine) (see len' te ra' ta): A group of animals without a body-cavity but the name implies that it has been combined with the intestine.
- Cœnocyte** (Gr. *kinos*, common + *cytos*, cell) (see' no site): A single cell wall containing many nuclei.
- Coppice sprouts** (from *copiez*, to cut) (kop' pis): Sprouts which spring up from stumps in woodland which has been cut.
- Conidiospores** (co nid' e o spores): Zoöspores which are formed in a conidium, which is a cone-shaped spore case of certain fungi.
- Conjugation** (Lat. *cum*, together with + *jugare*, to yoke) (kon' ju ga' shun): The meeting or fusing of two cells.
- Contact poison**: A poison which kills insects by coming in contact with their bodies.
- Cork**: A soft part of the bark.
- Corm** (Gr. *kormos*, a trimmed tree trunk): A compact underground stem.
- Cor'mel**: A little corm.
- Corolla** (Lat. *corolla*, little crown or garland) (ko rol' lah): The whorl of a flower comprising the petals.
- Corpuscle** (Lat. *corpusculum*, a small body) (kor' pus l): A small body in the blood.
- Cor'tex** (Lat. bark): The fleshy portion of a root surrounding the stele.
- Corymb** (Lat. *corymbus*, a flower or fruit cluster) (kor' imb): A flat topped flower cluster, each flower on a separate pedicel, and arising separately from a common stem.
- Cotyledon** (Gr. *kotyledon*, socket or cavity) (cot il e' don): The seed leaves which are formed in the seed before it is planted.
- Cra'nial nerves**: The nerves which issue from the cranium.
- Crop**: The part of the alimentary canal of a bird in which food is stored and moistened before digestion.
- Crop rotation**: A system of alternating crops on a parcel of land to avoid depleting its fertility or to fight weeds or insect pests.
- Crossbreeding**: Interbreeding individuals of different races or species to increase variation in the offspring.
- Cross-pollination**: Transfer of pollen from one flower to another.
- Culture**: A growth of bacteria or protozoans for examination or study.

- Cutic'ular hairs:** Hairs which arise from the cuticle or outer layer of the body.
- Cuttings:** Portions cut from the stems of plants and set out in soil or water to start new plants.
- Cytoplasm** (Gr. *kytos*, vessel + *plasm*, anything formed) (si' to plaz m): The protoplasm of a cell surrounding the nucleus.
- Cyme** (Gr. *kyma*, something swollen) (sīm): A flower cluster similar to a corymb but wherein the central flowers open before the others.
- Dar'winism:** A theory which explains evolution as having taken place by natural selection.
- Deciduous** (Lat. *decidere*, to fall) (de sid' u us): Said of trees the leaves of which fall periodically.
- Dehiscent fruit** (Lat. *de* + *hiscere*, to open) (de his' sent): A fruit which opens when its seeds are to be discharged.
- Deliquescent tree** (Lat. to melt or dissolve) (del e kwes' sent): A tree the top of which spreads out as in the elm.
- Delirium tremens** (Lat. trembling delirium) (de lir' e um tre'menz): A nervous breakdown due to excessive use of intoxicants.
- Descent** (Lat. *scandere*, to climb) (de sent'): See evolution.
- Des'erts:** Regions of the earth which are devoid of life due to absence of sufficient moisture or heat.
- Determiners** (Lat. to limit) (de ter' min ers): Theoretical bodies which cause heredity to manifest itself. They are probably within the chromosomes.
- Dichogamy** (Gr. *dicha*, asunder + *gamos*, marriage) (di kog' a me): A method of preventing self-fertilization wherein pistils and stamens do not mature at the same time in the same flower.
- Dicotyle'don** (two seed leaves): See cotyledon. A plant having two seed leaves.
- Diffusion** (Lat. *diffundere*, to pour) (dif fū' zjun): A free mingling of the molecules of two or more gases.
- Digestion** (Lat. *digestio*, food dissolving) (di jes' chun): The preparation of food for absorption.
- Dimorphous** (Gr. *di* + *morphe*, form) (di mor' fus): In plants, of flowers of two forms. Especially in regard to stamens and pistils of two lengths.
- Diœcious** (Gr. *di* + *oikos*, a house) (di e' shus): Of two households. Said of plants which bear unisexual flowers on separate individuals.
- Dipnoans** (Gr. *di* + *pnoi*, air, breathing) (dip' no an): The lung fishes, because they have two methods of breathing.
- Discontinuous variations:** Mutations.
- Disinfec'tion:** Destruction of bacteria. See infection.
- Dissect** (Lat. to cut away) (dis sect'): The cutting of plant and animal tissues for their examination and study.
- Dominant** (Lat. *dominus*, master) (dom' in ant): A dominant character is one which obscures a recessive character which opposes it in first generation hybrids.
- Drupe** (Lat. *drupa*, an overripe olive): A fleshy fruit with a single stone.

- Echinodermata** (Gr. hedgehog skin) (e ki' no der' mah tah): A phylum of animals comprising the starfishes and their allies.
- Ecology** (Gr. a discourse on homes) (e kol' o je): A study of the relation of life to environment.
- Ectoderm** (Gr. *ectos*, outside + *derma*, skin) (ek' tō derm): The outer tissue of an animal.
- Elasmobranch** (Gr. *elasmos*, plate + *branchia*, gill) (e las' mo brank): Any one of a group of fishes comprising the sharks and their allies.
- Elater** (Gr. a driver) (el' at er): A thread with spiral markings borne among the spores of some slime molds and liverworts.
- Ele'ment**: One of the simple, uncombined chemical substances.
- Em'bryo** (Gr. *embryon*, a young one): The developing individual before sprouting, hatching, or birth.
- Embryology**: The study of embryos.
- Emulsion** (Lat. *emulgere*, to milk out) (e mul' shun): A mixture of oil in water, or some other insoluble liquids, so that one is suspended in the other in fine globules.
- Endoderm** (Gr. *endo*, within + *derma*, skin) (en' dō derm): The innermost of the three germ layers. The lining of the digestive tract.
- Endogenous** (Gr. growing within) (en doj' e nus): A stem of a monocotyledonous plant which grows by adding tissue throughout its interior and not on the outside only as in an exogenous stem.
- Endosperm** (Gr. *endon*, within + *sperma*, seed) (en' do sperm): The food in a seed from which the embryo receives nourishment.
- Ensilage** (from Fr. *silo*) (en' se lāj): Material which is preserved in a silo.
- Environment** (Fr. *environ*, about) (en vi' run ment): The place, with its physical and biological influences, where an organism lives.
- Enzyme** (Gr. *en* + *zyme*, leaven) (en' zim): A substance which causes chemical action to take place without being consumed itself.
- Epidermis** (Gr. outer skin) (ep e der' mis): The outside tissue of the skin.
- Epiphyte** (Gr. *epi* + *phyton*, plant) (ep' e fite): A plant which is supported by another plant but not nourished by it.
- Erosion** (Lat. *erodere*, to gnaw off) (e ro' zjun): The wearing away of rock by water and other agencies.
- Eugenics** (Gr. well-born) (u jen' iks): The science of being well-born.
- Eustachian tube** (*Eustachio*, an Italian physician) (u stay' kee an): The tube which leads from the pharynx to the middle ear.
- Euthenics** (u then' iks): The science of improving life by making the environment better.
- Evolution** (Lat. *e* + *volvere*, to roll) (ev o lū' shun): The progress of life by descent from the simple to the complex.
- Excretion** (Lat. *excretus*, to sift out) (eks kre' shun): Elimination of waste products from a plant or animal.
- Excurrent tree** (Lat. *ex* + *currere*, to run) (ex cur' rent): A tall, slender tree with the main stem running to the top.



- Exogenous** (Gr. growing on the outside) (ex oj' e nus): See endogenous.
- Famine** (Lat. *fames*, hunger) (fam' in): General scarcity of food.
- Fascicle** (Lat. *fasciculus*, a little bundle) (fas' sik l): A bundle of flowers, leaves, stems, or roots.
- Feeble-mindedness**: Subnormal mentality.
- Fe'ral**: Said of a domesticated species which has become wild again.
- Fermenta'tion** (Lat. *fermentum*): Chemical change of substances through the action of enzymes, bacteria, or yeasts.
- Fertilization** (Lat. *fertilis*, fruitful): Union of an egg and sperm to form an oöspore.
- Fer'tilizers**: Materials which are put on land to improve the chemical condition of the soil for plant growth.
- Fi'brin** (Lat. fiber): An albuminous substance in blood which aids it in clotting.
- Fi'brous roots**: Long slender roots.
- Fibrovas'cular bundles**: Bundles of tubular cells which transport sap.
- Fission** (Lat. *fissus*, cleft) (fish' un): Cell division, as in bacteria, where the cell divides into two equal parts.
- Flagellum** (Lat. whip) (fla' jel um): A whip-like lash projecting from a cell.
- Fleshy roots**: Roots which have food or water stored in their tissues.
- Follicle** (Lat. *folliculus*, a little bag) (foll' ik el): A fruit of one carpel which dehisces along its ventral suture.
- For'estry**: The business of maintaining trees for a profit.
- Formula** (for' mū lah): A number of chemical symbols which show the composition of a chemical compound. A recipe.
- Fossils** (Lat. *fodere*, to dig) (fos' sil): The remains of plants and animals which have been preserved in the earth.
- Fronds**: The leaves of ferns.
- Fruit**: A ripened ovary and any floral parts which may be attached.
- Fumigate** (Lat. *fumus*, smoke) (fū' me gate): To destroy bacteria by poisonous gases.
- Function** (Lat. perform) (funk'shun): The useful action of a plant or animal structure or substance.
- Fungus**, pl. **fungi** (Lat. a mushroom) (fun' gus): Plants, usually without chlorophyll, and comprising the yeasts, molds, bacteria, and their allies.
- Gamete** (Gr. a spouse) (gam' ēt): One of two cells which must unite together to form a zygospore.
- Gametophyte** (Gr. *gametes* + *phyton*, plant) (gam' et o fite): The generation in the life cycle of a plant which bears the gametes, or eggs and sperms.
- Ganglion**, pl. **ganglia** (Gr. a little tumor) (gang' gle on; gle ah): A group of nerve cell bodies from which the fibers arise.
- Gas' tric juice**: The digestive juice which is secreted by the walls of the stomach.
- Gastrula** (Gr. *gaster*, stomach) (gas' troo lah): An early embryological stage following the blastula stage and wherein the endoderm is differentiated.
- Genus**, pl. **genera** (Lat. a race) (jee' nus; jen' er ah): A group of closely related species.

- Geotropism** (Gr. *Ge*, earth + *tropein*, turn) (je ot' ro pizm): A response to the force of gravity.
- Germination** (Lat. *germinare*, to sprout) (jer' min a' shun): The starting of growth in a pollen grain or seedling.
- Gland** (Lat. *glans*, an acorn): Any organ which secretes material for excretion or use.
- Grafting**: Union by growth of a desired species of plant to an unknown seedling or to a less desired stock.
- Gutta'tion** (Lat. *gutta*, drop): Drops of liquid exuded from the leaves of plants when transpiration is checked by high humidity.
- Gymnosperm** (Gr. *gymnos*, naked + *sperm*) (jim' no sperm): Plants which bear their seeds from ovules which are not enclosed in ovaries.
- Hæmoglobin** (Gr. *haima*, blood + *globos*, sphere) (hem' o glo' bin): The red protein in the blood.
- Hered'ity** (Lat. *herer*, heir): Transmission of characteristics from generation to generation.
- Hesperidium** (Gr. *Hesperides*, mythological characters of the garden of golden apples) (hes per id' e um): A berry, such as the orange, having a thick rind.
- Heterogamy** (Gr. *heteros*, different + *gamos*, marriage) (het' er og' a me): Fertilization or conjugation of unequal gametes.
- Heterogenesis** (Gr. *heteros*, different + *genesis*, be born) (het' er o jen' e sis): Alternation of generations. A theory which attempts to explain mutations.
- Hibernation** (Lat. *hibernus*, wintry) (hi' ber nā' shun): A winter rest attended by reduced physiological activity.
- Humidity** (Lat. *humere*, to be moist) (hū mid' it e): Amount of moisture in the air.
- Hu'mus** (Lat. ground): A black soil formed from the disintegration of organic matter.
- Hy'brid** (Lat. *hybrida*, mongrel); The product of mating between different races or species.
- Hybridization** (hi brid iz a' shun): The production of hybrids.
- Hydrotropism** (Gr. *hydor*, water + *trope*, a turning) (hi drot' ro pis m): A response of a plant or animal to the influence of water.
- Hygroscopic** (Gr. *hygros*, wet + *scope*, to see) (hi' gro skop' ik): Water in material which has been absorbed from the air.
- Hypha** (Gr. *hyphe*, a web): A filament of a fungus plant.
- Hypocotyl** (Gr. *hypo*, under + *cotyle*, a hollow) (hī po kot' il): The axis or stem of an embryo below the cotyledons.
- Immunity** (Lat. *immunis*, free from a public service) (im mū' nit e): Freedom from infections or contagious disease.
- In'breeding**: Breeding closely related animals.
- Indusium** (Lat. *induere*, to put on) (in dū' she um): A scale covering the sporangia of ferns.
- Infection** (Lat. *infectus*, to dip into) (in fek' shun): Inoculation, contagion.

- Inflorescence** (Lat. to bring to blossom) (in' flo res' sens): Arrangement of flowers in a flower cluster.
- Influenza** (Ital. from *influence* of stars) (in' flu en' zah): A cold caused by bacteria.
- Inheritance** (Lat. *heres*, heir) (in her' it ans): Heredity.
- Intest'ine** (Lat. *intestinus*, internal): That part of the alimentary canal between the stomach and anus.
- Involucre** (Lat. *involvere*, to wrap up) (in' vo lu' ker): A whorl of bracts around a flower or flower cluster.
- Iris** (Gr. rainbow): The colored, muscular portion of the eye surrounding the pupil.
- Irritability** (Lat. *irritatus*) (ir' rit a bil' it e): Ability to respond to a stimulus.
- Isogamy** (Gr. *iso*, equal + *gamos*, marriage) (i sog' am e): Union in conjugation of equal gametes.
- Isolation** (Lat. *insula*, island) (i' so lā' shun): Separation by barriers from other varieties of the same species.
- Karyokinesis** (Gr. *karyon*, nucleus + *kinesis*, movement) (kar e o kin e' sis): Mitosis.
- Lacteal** (Lat. *lactis*, milk) (lak' te al): One of the small tubes which carry chyle from the intestine to the lymphatic duct.
- Larva** (Lat. *larva*, specter) (lar' va): The young of an invertebrate.
- Layering**: Burying a branch of a plant until it takes root for transplanting.
- Legume** (Lat. *legumen*, any pea plant) (leg' ūme: le gūm'): A pod dehiscing along two sutures along one of which the seeds are attached.
- Lenticel** (Lat. a little lentil or lens) (len' tis el): A breathing opening in a plant stem.
- Linebreeding**: Breeding ancestor to offspring to perpetuate and intensify certain characters.
- Lip'ase**: An enzyme which digests fats. Steapsin.
- Loam**: A fertile soil composed of clay and sand and containing organic matter.
- Locule** (Lat. *locus*, place) (lok' ūl): A compartment or cell of an ovary.
- Loess** (lō es): A yellow, fertile soil formed by a combination of wind and water action.
- Lo'ment** (Lat. *lavare* + *lotum*, bean-wash used as a cosmetic): A legume which has been constricted between each of the seeds.
- Lymph** (limf): The nutritive fluid derived from the blood which bathes the tissues of the body and returns to the heart through the lymphatic vessels.
- Macronu'cleus** (Gr. *macro*, great + *nucleus*): The larger of two nuclei when two are present in one cell.
- Malforma'tions** (Lat. *male*, ill + *formation*): Deformities.
- Maturation** (Lat. *maturus*, mature) (mat u rā' shun): The development of sperms and eggs.
- Meg'aspore** (Gr. large spore): The larger of two kinds of spores produced by the same species of plant.

- Megasporan'gium** (Gr. large sporangium): See sporangium. The sporangium which produces the megaspores.
- Melanism** (Gr. *mela*, black) (mel' a niz m): The appearance of black individuals by mutation.
- Mendelian variations**: Variations which follow one of Mendel's laws.
- Mesoderm** (middle skin) (mes' o derm): The median of the three germ layers from which bones, muscles, blood vessels, etc. are developed.
- Mesophyll** (Gr. *mesos*, middle + *phyllon*, leaf) (mes' o fil): Tissue in the middle of the leaf between the upper and lower epidermis.
- Metamorphosis** (Gr. *meta*, after + *morphe*, form) (met' a mor' fo sis): The changes in an animal in developing from the egg to the adult.
- Microspore'** (small spore): The smaller of two kinds of spores produced by the same species of plant.
- Microsporan'gium** (small spore case): See sporangium. The smaller of two kinds of spore cases produced by the same species of plants or the one which bears microspores.
- Micropyle** (Gr. *mikros*, small + *pyle*, gate): A small opening in an ovule for the entrance of the pollen tube: it persists in the seed.
- Micronu'cleus** (small nucleus): The smaller of two nuclei when two are present in one cell.
- Migration** (Lat. *migrare*) (mi grā' shun): Passage of animals from one place to another, usually periodically, for food or breeding purposes.
- Mitosis** (Gr. *mitos*, thread) (mi to' sis): Cell division wherein chromosomes become visible. Karyokinesis.
- Mode** (Lat. *modus*, measure): The average, or most favorable condition.
- Molecule** (Lat. *moles*, mass) (mol' e küle): A combination of atoms to form the unit particle of a chemical compound.
- Monocotyledon** (one seed leaf) (mono kot e le' dun): A plant which bears seeds with one cotyledon.
- Monœcious** (Gr. *monos*, one + *oikos*, house) (mo ne' shus): Hermaphrodite. Plants bearing monosexual flowers of both sexes on the same plant as in the squash.
- Mulch**: A dressing of powdered soil or some other material on the surface of planted ground to conserve moisture.
- Multiple fruits**: Fruits consisting of numerous ripened ovaries consolidated into one mass, as the mulberry.
- Mutation** (Lat. *mutare*, change) (mu tā' shun): A heritable change from internal causes in the offspring of an organism.
- Mycelium**, pl. **mycelia** (Gr. a fungus) (mi se' le um; le ah): A mat of hyphæ.
- Natural selection**: Nature's method of improving life by elimination of the unfit and preservation of the most fit to be the parents of the next generation. Darwinism.
- Nec'tar** (Gr. *nektar*, the drink of the gods): A sweet fluid secreted by flowers to attract insects which carry pollen.
- Neuron** (Gr. nerve) (nū' ron): A nerve cell.

- Notochord** (Gr. *notos*, back + *chorde*, string) (no' to kord): A rod of hardened cells in vertebrate embryos and some adults, extending the length of the body below the nerve cord and dorsal to the intestine.
- Nucellus** (Lat. *nucella*, a small nut) (nū sel' us): The endosperm or body of the ovule in which food is stored to be absorbed by the embryo.
- Nucleus** (Lat. kernel) (nū' kle us): The central organ of the cell.
- Nut**: A hard, indehiscent, usually single seeded fruit.
- Oögonium** (Gr. *oon*, an egg + *gonos*, offspring) (o' o go' ne um): The structure in a plant where the egg cells are produced.
- Oöspore** (Gr. egg spore) (o' o spore): A fertilized egg.
- Operculum** (Lat. *operire*, to cover) (o per' kū lum): A protecting covering.
- Order** (Lat. *ordo*) (or' der): An assemblage of genera having certain characteristics in common.
- Or'gan**: A structure which is a part of a plant or animal and which performs a special function.
- Orthogenesis** (Gr. *orthos*, straight + *genesis*) (or' tho jen' e sis): A theory of evolution.
- Osmosis** (Gr. to push) (oz mo' sis): Diffusion of the molecules of a solution through an organic membrane.
- Ostracoderms** (Gr. *ostracho*, shell + *derma*, skin) (os trak' o derms): Extinct fish-like creatures with a heavy armour.
- Outbreeding**: Breeding a pure stock to an unrelated strain.
- Ovary** (Lat. *ovum*, egg) (o' var e): The place where eggs are developed.
- Ovule** (Gr. little egg) (o' vūl): The body in the ovary which develops into the seed. It was formerly thought to be an egg.
- Oxidation** (from oxygen) (oks e dā' shun): The combination of oxygen with other substances in chemical union.
- Pal'isade cells** (Lat. *palus*, stake): Elongate cells in leaves.
- Pal'mate leaves** (Lat. *palma*, hand): Leaves without any chief vein, but having several diverging from the petiole.
- Pancreas** (Gr. *pan*, all + *kreas*, flesh) (pan' kre as): A digestive gland which secretes a digestive juice and supplies an internal secretion to the blood.
- Panicle** (Lat. *panicula*, a tuft) (pan' ik l): A compound raceme or corymb usually having the shape of a cone.
- Paraphyses** (Gr. *para*, beside + *phyo*, produce) (par aff' e sez): Extra structures in moss plants and others.
- Par'asite** (Gr. *para*, beside + *siteitn*, to feed): An organism which feeds on another living thing.
- Pasteurization** (pas ter iz' a shun): Heating liquids until the harmful bacteria are killed, but not until the liquid boils.
- Pedicel** (Lat. *pes*, foot + *cel*, diminutive) (ped' e sel): A stem supporting a single flower or fruit.
- Peduncle** (Lat. *pes*, foot + *cle*, diminutive) (pe dun' kl): A stem supporting a cluster of flowers or fruits.



- Pepo** (Gr. *pepon*, gourd) (pe' po): A form of the berry such as the gourd or melon.
- Perennial** (Lat. *per*, through + *annus*, year) (per en' ne al): A plant living through several years.
- Pericarp** (Gr. *peri*, around + *karpōs*, fruit) (per'e karp): The matured wall of the ovary.
- Pet'als** (Gr. *petalon*, leaf): The parts of the corolla.
- Petiole** (Lat. *petiolus*, little foot) (pet' e ol): A leaf stem.
- Pharynx** (Gr. gullet) (far' rinks): A chamber at the junction of the mouth and esophagus.
- Phloëm** (Gr. *phloos*, bark) (flo' em): The outermost part of a fibrovascular bundle. The sieve-tubes.
- Photosynthesis** (Gr. *photos*, light + *synthesis*, putting together) (fo to sin' the sis): The production of carbohydrates in plant tissues under the influence of light.
- Phototropism** (Gr. *photos*, light + *trope*, a turning) (fo tot' ro piz m): The response of a plant or animal to light.
- Phylum**, pl. **phyla** (Gr. *phylon*, race or tribe) (fi' lum; fi' lah): A primary division in classification comprised of related classes.
- Physiology** (Gr. *physis*, nature + *logos*, discourse) (fiz e ol'o je): A study of the functions of a living organism.
- Pin'ate leaf** (Lat. *pinna*, feather): Leaves with a main vein as in a feather.
- Pis'til** (Lat. *pistillum*, a pestle): The ovary and its extra parts in the flower.
- Plumule** (Lat. *plumula*, a little feather) (ploo' mül): The first bud in the embryo of a seed.
- Pollen** (Lat. fine flower) (pol' len): The microspores of seed-plants.
- Pollen tube**: The male gametophyte of seed-plants.
- Pollina'tion**: The transfer of pollen from the anthers to the stigmas.
- Polydactylism** (Lat. many fingers) (pol e dak' til ism): The appearance of extra fingers on the hand.
- Pome** (Lat. *pomum*, fruit) (pōm): A fruit like the apple containing a core.
- Prepotency** (Lat. *pre*, before + *potis*, able) (pre po' ten se): Ability of a breeding animal to stamp his offspring strongly with his special characteristics.
- Procambium** (Lat. *pro*, before + *cambium*, exchange) (pro cam' be um): Cells similar to cambium which precede it in position and function in a young stem.
- Proglottids** (Gr. *pro*, forward + *glotta*, tongue) (pro glot' tids): The sections of a tape worm's body.
- Protein** (Gr. *protos*, first) (pro' te in): An essential constituent of living things. It contains nitrogen and exists in many forms.
- Prothallium** (Gr. *pro*, before + *thallos*, a sprout) (pro thal' le um): The gametophyte of ferns and their allies.
- Protonema** (Gr. *protos*, first + *nema*, thread) (pro to ne' ma): An alga-like growth from a moss spore from which the moss plants grow.

- Protoplasm** (Gr. *protos*, first + *plasma*, something formed) (pro' to plas m): That part of plants and animals which is alive.
- Protozo'a** (Gr. first animal): The single celled animals.
- Pseudopodia** (Gr. *pseudes*, false + *pons*, foot) (sū' doe po' de um): Protoplasmic processes put forth by protozoans.
- Ptomaine** (Gr. *ptoma*, a corpse) (toe' mane): A poisonous alkaloid believed to be caused by the action of bacteria in food. (Also pro to' mā ēn.)
- Ptyalin** (Gr. *ptyal*, spittle) (ti' al in): The starch fermenting enzyme in saliva.
- Pupa** (Lat. *pupa*, puppet) (pū' pa): The resting stage of an insect between the larval and adult stages.
- Pylorus** (Gr. gatekeeper) (pi lor' us): The valve which guards the passage from the stomach to the intestine.
- Pyrenoid** (Gr. *pyrena*, the stone of a fruit) (pi re' noid): A dense body in a chloroplast.
- Quar' antine** (Fr. *quarante*, "forty days") (kwor' an tēn): Isolation of individuals having a contagious disease to prevent its spread.
- Raceme** (Lat. *racemus*, a bunch of grapes) (ra sēm'): A flower cluster with a central axis and lateral pedicles blossoming at the base first.
- Races**: Smaller divisions than species in the classification of plants and animals.
- Race suicide**: Failure of a social group to produce sufficient children to maintain its numbers.
- Radicle** (Lat. *radix*, root) (rad' ik l): The root of a sprouting seed.
- Reason** (Fr. *raison*): A complex mental process which culminates in a conclusion. Authorities differ as to what reason really is.
- Recapitula'tion the'ory**: A theory that the individual sums up the evolutionary development of the species in developing from the egg to the adult.
- Receptacle** (Lat. a reservoir) (re cep' tak l): The base or axis of a flower from which the parts arise.
- Reces'sive**: See dominant.
- Reflex** (Lat. *reflexus*, reflect) (re' fleks): A response to a stimulus wherein the brain does not function.
- Refraction** (Lat. *refringere*, break) (re frak' shun): A turning of rays of light from their direct course on passing from one medium to another.
- Refrigeration** (Lat. *frigus*, coolness) (re frij' er a' shun): Process of keeping fermentable materials cool to prevent the growth of bacteria.
- Ren'nin** or **ren'net** (Anglo-Saxon, to run): A milk curdling enzyme made from the wall of the stomach or secreted by the stomach.
- Repellents** (from repel) (re pel' lent): A chemical used to keep away harmful insects.
- Reproduction** (from produce) (re' pro duk' shun): The bringing forth or production of offspring.
- Respiration** (Lat. *spirare*, to breathe) (res' pir a' shun): Taking in of oxygen and elimination of carbon dioxide.
- Response** (Lat. *spondere*, to promise) (re spons'): A movement which follows an impulse caused by a stimulus.

- Retina** (Lat. *rete*, a net) (ret' in ah): The sensitive coat of the eye to which the optic nerve is distributed.
- Rever'sion**: See atavism.
- Rhizoids** (Gr. *rhiza*, a root + *eidos*, resemblance) (riz' zoid): Hair-like processes from the cells of moss and fern gametophytes for absorption of water.
- Rhizome** (Gr. *rhizoma*, mass of roots or a stem) (riz zōm'): A rootstock, or an underground stem.
- Rodent** (Lat. *rodere*, to gnaw) (ro' dent): Any animal in the group of gnawers including the rabbit, squirrel, and their allies.
- Rogues** (rō g z): Mutations which fall below the standard of the plant and animal breeder.
- Root'stock**: A rhizome.
- Run'ners**: Stems which grow out to establish a new plant some distance from the parent.
- Saltations** (Lat. *salire*, to leap) (sal tā' shun): A mutation.
- Samara** (Lat. elm seed) (sam' ar ah: sa mā' ra): A winged fruit.
- Sanitation** (Lat. *sanitas*, health) (san' it a' shun): Scientific prevention of disease.
- Sap'ling** (from sap): Any young tree.
- Saprophyte** (Gr. *sapros*, rotten + *phyton*, plant) (sap' ro fite): A plant which lives on decaying organic matter.
- Scolex**: The head of a tapeworm.
- Scutellum** (Lat. *scutella*, salver, or *scutum*, shield) (skū tel' lum): A structure of the embryos of grain seeds which absorbs food from the endosperm.
- Sedentary soil** (Lat. *sedere*, to sit) (sed' en ta re): A soil which has remained where it was formed. Not transported.
- Segregation** (Lat. *se*, aside + *gregis*, a herd) (seg' re gā' shun): Separation from others.
- Selection** (Lat. *se*, aside + *legere*, to gather) (se lek' shun): Chosing of the most fit by eliminating the unfit.
- Sepals** (a coined word) (se' pal): The leaf-like structures which compose the calyx and surround the petals.
- Serum** (Lat. cured) (sē' rum): The liquid of the blood or that which exudes from wounds. An extract of the blood used in combating disease.
- Sessile** (Lat. *sessilis*, sitting) (ses' sil): Attached without a stem.
- Silique** (Lat. *siliqua*, a pod) (se leek'): An elongate pod containing a partition and opening along two sutures as in mustard.
- Sor'us**, pl. **sori** (Gr. *soros*, a heap): A cluster of sporangia in ferns.
- Species** (Lat. kind or sort) (spee' sheez): A group of plants or animals which are alike and have common differences from all other kinds.
- Sperm** (Gr. *sperma*, seed): A male gamete.
- Sperm'aries**: Bodies which produce sperms.
- Spike** (a large nail): A cluster of sessile flowers on a common axis.
- Spiracle** (Lat. *spirare*, to breathe) (spir' ak l): Any opening for respiration.
- Sponta'neous genera'tion**: Reproduction without parents. There is no evidence to prove that it ever takes place.

**Sporangium** (Gr. *spora*, a seed + *aggeion*, a vessel) (spo ran' je um): A structure which produces spores. A spore case.

**Spore** (Gr. *sporos*, a sowing) (spōr): A cell which is capable of developing into a plant. Used in various combinations to indicate kinds of spores.

**Sporophore** (Gr. spore + *phor*, to bear or carry) (spo' ro for): A stalk or other structure which bears spores.

**Sporophyte** (Gr. *sporos* + *phyton*, plant) (spo' ro fite): A plant which bears spores. The asexual generation in the alternation of generations.

**Sporophyll** (Gr. *sporos* + *phyllon*, leaf) (spo' ro fil): A leaf which bears spores.

**Sports**: Mutations.

**Sporula'tion**: Production of spores.

**Sta'mens** (Lat. warp or thread): The structures which bear pollen.

**Statocyst** (Gr. *statos*, standing + *cystis*, a sac) (stat o sist): A structure in invertebrates containing particles and sensory hairs which is used as a balance organ.

**Steap'sin**: See lipase.

**Stele** (stee' lee): The central axis of a root.

**Sterilization** (Lat. *sterilis*, barren) (ster' il i zā' shun): Any treatment given fermentable substances so that they will not decay. To render useless the sex organs.

**Stig'ma** (Gr. *stigma*, a point): The end of the pistil where the pollen is received.

**Stimulus** (Lat. a goad) (stim' u lus): That which starts a nervous impulse. A quickening of physiological activity.

**Stip'ules** (Lat. *stipula*, stem): Leaf-like structures which grow from the base of a petiole.

**Sto'lon** (Lat. *stolo*, a sucker): A shoot from the base of a plant, which generally takes root and starts another individual.

**Stomate**, pl. **stomates** (Gr. *stoma*, mouth) (sto' māt): Small openings in the epidermis of leaves permitting diffusion of gases.

**Stone cell**: Hard cells in the stems of plants.

**Style** (Gr. *stylos*, a pillar): A slender process supporting the stigma and attaching it to the ovary.

**Superposi'tion** (Lat. *super*, over + position): A geological law that the strata of rocks which lie nearest the center of the earth were deposited before those which lie above.

**Symbiosis** (Gr. living together) (sim' bi o' sis): A communal life where two species are mutually beneficial.

**Symmetry** (like measure) (sim' met re): Alike on both sides or around a common center.

**Synergids** (Gr. *syn*, with or together + *erg*, work) (sin er' jids): Cells which assist others in doing their work.

**Taxonomy** (Gr. *taxis*, arrangement + *nomos*, law) (taks on' o me): The scientific classification of plants and animals.

**Teg'men** (Lat. *tegmen*, covering): The inner seed coat. Also spelled teg' umen.

**Teleostome** pl. **teleos' tomi** (Gr. *teleos*, perfect + *stoma*, mouth) (tel' e o stōm): The bony fishes, the lower jaws of which are completely formed.

- Tentacle** (Lat. *tentaculum*, a feeler) (ten' ta kul): A feeler or a grasping organ.
- Tes'ta** (Lat. *testum*, an earthen vessel): The outer seed coat.
- Tet'raspores** (four spores): Spores which are developed in groups of four from two divisions of a germ cell.
- Tourniquet** (from *tour*) (toor' ne ket): A bandage which can be tightened by twisting a stick through it. It is used to stop the flow of blood.
- Toxins** (Lat. *toxicum*, poison) (toks' in): Poisons produced by bacteria or in other ways.
- Trachea** (Lat. windpipe) (trā' ke ah): A tube through which air passes in respiration.
- Tracheid** (trā' ke id): A slender cell for transporting sap in a plant stem.
- Transpiration** (Lat. *trans*, through + *spirare*, to breathe) (tran' spir a' shun): To give off vapors or gases in evaporation or excretion.
- Trimorphous** (tri mor' fus): Of three forms. See dimorphous.
- Tropism** (Gr. *trope*, turn + *ismus*, process) (tro' pizm): A movement due to an external stimulus.
- Trypsin** (trip' sin): A digestive enzyme which acts on proteins.
- Tuber** (Lat. a tumor): A short underground stem, as the potato.
- Umbel** (Lat. diminutive of *umbra*, shade) (um' bel): An umbrella shaped cluster of flowers or fruits wherein the pedicels arise from a common point.
- Vacuole** (Lat. *vacuus*, empty) (vak' u ōl): A space in a cell.
- Vascular** (Lat. *vasculum*, a small vessel) (vas' kū lar): Having veins or ducts for conveying blood or sap.
- Vein** (vāne): A bloodvessel which conveys blood toward the heart.
- Vesicle** (Lat. *vesica*, bladder) (ves' ik l): A small chamber or sac.
- Vestigial structures** (Lat. *vestigium*, a foot track) (ves tij' e al): Structures, such as the appendix, which probably once had a function to perform, but which are now useless.
- Vil'lus** (Lat. *villus*, shaggy hair): A hair-like projection, as the absorbing structures in the intestine.
- Vitamins** (Lat. *vita*, life) (vi' ta minz): Little known proteins in food which are essential to health.
- Vol'va** (Lat. veil): A sheath of some mushrooms. It is broken as the mushroom develops.
- Xenia** (Gr. *xenos*, strange) (ze' ne ah): The appearance of the effects of hybridization in the endosperm of the seeds of grains in the hybrid seed.
- Xylem** (Gr. *xylon*, wood) (zi' leem): The woody portions of a stem.
- Yolk sac**: An embryonic structure of vertebrates which contains the yolk of the developing egg.
- Zoöspore** (Gr. *zoon*, animal + spore) (zo' o spör): A spore which is able to swim like an animal.
- Zygomorphic flowers** (Gr. *zygon*, yoke + *morphos*, form) (zī go mor' fik): Flowers which are alike on two sides as the violet and pea.
- Zygospore** (Gr. *zygon*, yoke + spore) (zī' go spör): A spore formed by the union of two similar gametes.



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